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Charming e-cigarette users with distorted science: Examining the impact of misleading and false claims about nicotine on beliefs about the tobacco industry

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Charming e-cigarette users with distorted science: Examining the impact of misleading and false claims about nicotine on beliefs about the tobacco industry

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1   **Abstract**

2   **Objective.** To examine the role of social media in promoting recall and belief of distorted

3   science about nicotine and whether recall and belief in turn predict tobacco industry beliefs.

4

5   **Design.** Young adults 18-34 ($N=1225$) were surveyed cross-sectionally via online Qualtrics

6   panel. The survey assessed recall and belief in three claims about nicotine and COVID-19 and

7   three about nicotine in general followed by assessments of industry beliefs and use of social

8   media. Ordinal logistic regression with robust standard errors controlling for gender,

9   race/ethnicity, education, current e-cigarette use, and age was used to examine relationships

10   between variables.

11   **Results.** Twitter use was associated with higher odds of recall (OR=1.21,95% CI=1.01, 1.44)

12   and belief (OR=1.26,CI=1.04, 1.52) in COVID-19 specific distorted science. YouTube use was

13   associated with higher odds of believing COVID-19 specific distorted

14   science (OR=1.32,CI=1.09, 1.60). Reddit use was associated with lower odds

15   of believing COVID-19 specific distorted science (OR=0.72,CI=0.59, 0.88). Recall

16   (OR=1.26,CI=1.07, 1.47) and belief, (OR=1.28,CI=1.09, 1.50) in distorted science about nicotine

17   in general as well as belief in distorted science specific to COVID-19, (OR = 1.61,CI=1.34, 1.95)

18   were associated with more positive beliefs about the tobacco industry.

19   Belief distorted science about nicotine in general was associated with more negative beliefs

20   about the tobacco industry (OR=1.18,CI=1.02, 1.35).

21

22   **Conclusions.** Use of social media platforms may help to both spread and dispel distorted science

23   about nicotine. Addressing distorted science about nicotine is important, as it appears to be

24   associated with more favorable views of the tobacco industry which may erode public support

25   for effective regulation.

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27

28   **What this paper adds:**

29   This study provides evidence of the role of social media in both disseminating as well as

30   dispelling misleading and potentially harmful misinformation about nicotine and suggests a role

31   for counter messaging. Additionally, addressing misinformation about nicotine is important, as it

32   appears to be associated with more favorable views of the tobacco industry which may erode

33   public support for effective regulation.

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Strengths and Limitations of this Study

- This study uses a large sample size to answer a novel and timely research question examining the distorted information environment surrounding nicotine and COVID-19.
- This study addresses an understudied area of tobacco control research, namely tobacco users' perceptions of the tobacco industry and how this may play into public perception of their products, and by extension, how they are regulated.
- This study is cross-sectional and thus causality cannot be identified from the analysis.
- This study sample is large, however, it is not nationally representative and therefore limited in terms of external generalizability.

Background

48

49   Tobacco companies and some harm reduction advocates are promoting misleading and

50 even patently false claims about nicotine to frame efforts to regulate next generation nicotine

51 products as "anti-science." There is a legitimate need to differentiate the harmful consequences

52 of combustible cigarette (CCs) use from those of nicotine, as nicotine replacement therapy

53 (NRT) offers an evidence-based means to reduce the public health impact of smoking [1-3].

54 However, dissemination of unsubstantiated claims about nicotine as a harmless stimulant or even

55 a therapeutic method can undermine public health by promoting the use of an addictive

56 substance [4, 5]. The distortion of science to fit a pro-tobacco narrative has a long history [6],

57 and is now emerging to counter evidence of the dangers associated with e-cigarette (EC) use [7].

58 The tobacco industry has seized upon the affordances of social media to disseminate distorted

59 interpretations of science and misinformation about ECs [8, 9], often through the lens of harm

60 reduction [10]. The resulting impact threatens to position tobacco companies in a more positive

61 light as advocates for the health of former smokers instead of purveyors and marketers of a

62 harmful product, which in turn threatens to undermine regulatory efforts. This research examines

63 the potential role of social media in disseminating distorted science about nicotine both in the

64 context of the COVID-19 pandemic and in general, and the extent to which recall and belief in

65 such information affects beliefs about the tobacco industry.

66   Public understanding of the harms of nicotine are inextricably linked to harm perceptions

67 of CCs posing challenges to health communicators and practitioners [11]. The most recent

68 systematic literature review found that while most research showed relatively lower risk

69 perceptions for NRT and ECs compared to CCs, there remains confusion surrounding various

70 non-combustible products [1]. One study using data from the National Youth Tobacco Survey

5

71   found that between 22-33% of respondents believed smokeless products were *more* dangerous

72   than CCs [12]. Another sample of young adults found that more than half of respondents

73   erroneously believed that nicotine was the cancer-causing agent in CCs, and that the risks of ECs

74   and NRT were equal to that of CCs [5]. Many of the same misperceptions were even held by a

75   majority of physicians [13]. These mistaken beliefs are problematic in that they can deter

76   evidenced-based NRT treatment that reduces the burden of tobacco-related illness on current

77   smokers [11, 14, 15]. However, EC advocates have seized on this confusion regarding the risks

78   posed by nicotine to conflate scientific support for the evidence-based benefits of NRT for

79   helping smokers quit with unsubstantiated claims about the safety of ECs [11]. Moreover, media

80   purporting to "uncover the truth behind nicotine" [16, 17], and broader efforts by tobacco

81   companies to market next generation products like ECs as safe alternatives to smoking, "tobacco

82   free," or "clean nicotine" [18-20] represent deliberate attempts to undermine regulatory efforts

83   and by distorting scientific evidence.

84   Although nicotine is not responsible for many of the most well-known consequences of

85   smoking [21, 22], nicotine can harm the cardiovascular system [23-26], have adverse

86   consequences on neural development [27-30] and is an addictive substance with strong potential

87   for lifelong abuse [31]. The societal consequences of the widespread belief that nicotine is

88   harmless threatens to expand nicotine addiction far beyond current levels driven by smoking, as

89   beliefs about nicotine predict product use [5]. Recent research suggests that social media, in

90   particular, has a high volume of problematic information about nicotine and nicotine products

91   [9]. Thus, it is important to examine the prevalence and potential effects of such information,

92   particularly on EC users to whom much of this information is targeted [32, 33].

93   The ambiguity surrounding COVID-19 has made it a common topic of misinformation

94 [34], particularly with respect to the effects of nicotine. One prominent example is based on a

95 review of clinical data in Wuhan Province, China showing a significantly lower prevalence of

96 smokers among patients admitted to ICUs for COVID-19 in the early months of the pandemic

97 [35, 36]. These findings prompted an editorial [37] and the registration of clinical trials testing

98 the hypothesis that nicotine may prevent infection and progression of COVID-19 [38]. While the

99 clinical trials have not yet concluded, research conducted since does not support any therapeutic

100 or prophylactic benefits of nicotine on COVID-19 [38]. In fact, recent research has shown that in

101 addition to smoking increasing odds of disease progression and severe symptoms [39-41], a

102 recent systematic review strongly suggests that nicotine, including ECs and even smokeless

103 products, are a likely risk factor for infection and progression of COVID-19 [42]. Although more

104 research is needed to make definitive claims about the effects of nicotine, there is currently no

105 evidence supporting a therapeutic use for nicotine with respect to COVID-19. Despite the lack of

106 supporting evidence and significant evidence to the contrary, an analysis of twitter discourse

107 identified a substantial presence of content related to prevention or treatment of COVID-19 with

108 nicotine [43].

109   Whether a deliberate effort by EC advocates or a product of online discourse with

110 minimal moderation, the dissemination of distorted science about nicotine on social media poses

111 a barrier to public health. Researchers have identified a variety of potential impacts of such

112 information among EC users including bulk buying and increased usage [33]. Additionally, the

113 dissemination of information distorting the science of nicotine safety is likely to directly

114 undermine efforts to regulate the industry by creating more favorable views of ECs and the

115 companies who manufacture them. The most recent review of the literature suggests EC-related

7

116 content on social media tends to be favorable to EC use [44]. Moreover, analysis of social media

117 posts suggests an environment hostile to regulation [45] with a significant presence of sponsored

118 industry advocacy messaging [46]. The dissemination of distorted science positioning regulatory

119 efforts in opposition to public health threatens to further deceive the public regarding the safety

120 of nicotine and ECs [7]. The evidence to date highlights a need to examine the extent to which

121 distorted science about nicotine is disseminated on social media and its potential impact on

122 tobacco industry attitudes. Specifically, this work investigates the extent to which use of specific

123 social media platforms are associated with recall and belief in distorted science about nicotine.

124 We also aim to investigate the relationship between beliefs about the tobacco industry and recall

125 and belief in distorted science about nicotine.

126 **METHODS**

127 **Data Collection**

128 *Online Panel Survey*

129   We contracted with Qualtrics to recruit N=1225 participants ages 18-34 for a survey,

130 fielded June 4-June 11, 2021, to examine the relationship between exposure to and belief in

131 distorted science about nicotine in general and in the context of COVID-19, social media use,

132 and tobacco industry attitudes. An initial sample of N=2088 people consented to participate in

133 the study. Of those, n=495 failed an attention check asking to select a specific response, n=90

134 were removed for other quality control reasons (e.g. straight line responding), and n=278 were

135 removed for incomplete response sets leaving a final sample of N=1225. Participants were a

136 convenience sample and were aged 18-34 (M(SD)=26.95(4.85), 40.8% male, 70.27% white, with

137 39.39% reporting a high school diploma/GED or lower education. We oversampled for current

138 EC users (59.76%) with 75.27% reporting having ever used an ECs and having used ECs

139 products an average of 11.97 (SD=11.89) days in the last month.

140 *Patient and Public Involvement*

141 No patients or public were involved in the development of this research.

142 **Measures**

143 *Social media use*

144   Consistent with the literature, we assessed active (e.g. posting), passive (e.g. scrolling),

145 and social (e.g. commenting) elements of social media use [47]. Participants first indicated

146 whether they used several social media platforms. For each platform, a use index was calculated

147 based on the average of three items: whether the participant 1) checks content, 2) posts content,

148 and 3) responds to comments on each platform rarely (1), sometimes (2), or often (3). Table 1

149 provides summary statistics for both the percentage of our sample who used each platform as

150 well as the average amount of use.

151 *Recall and belief of distorted science indices*

152   COVID-19 related. Recall and belief indices for distorted science related to COVID-19

153 were calculated based on responses to three specific claims. The first claim that smokers are less

154 likely to be hospitalized for COVID-19 was related to the early review cited above and was

155 recalled by 12.53% with 11.65% believing it was either probably or definitely true. Claim two

156 represented the conclusions drawn by that study and the hypothesis then tested in future research

157 that "nicotine prevents the virus that causes COVID-19 from infecting cells" and was recalled by

158 10.35% and believed by 9.35%. Finally, the third claim that "chemicals in vaping liquid (e.g.

159 propylene glycol) sterilize the air to protect from COVID infection" represents a

160 misappropriation of a very old study [48] that was promoted as evidence to support EC use

9

161 during the pandemic. Similar to the previous claims, 10.78% recalled while 9.47% believed it

162 was probably or definitely true. Summative indices were calculated for each participant with

163 higher values indicating a given respondent recalled $M(SD)=0.33(0.74)$ and believed

164 $M(SD)=0.30(0.72)$ between zero and three misleading scientific claims.

165   General nicotine. Recall and belief in three claims about nicotine safety were assessed in

166 the same manner as above. Participants indicated whether they recalled and believed three

167 statements that have been promoted in either popular media or advertising for ECs: "Nicotine is

168 only addictive when smoked from a cigarette" was recalled by 14.02% and believed by 13.29%.

169 "Nicotine by itself is no more harmful than caffeine from a cup of coffee" was recalled by

170 31.09% and believed by 29.02%. Finally, "Nicotine is useful as a medical treatment for people

171 with mood, attention, or memory disorders" was recalled by 20.79% and believed by 22.66%.

172 Summative indices were calculated for each participant. A given respondent recalled

173 $M(SD)=0.66(0.83)$ and believed $M(SD)=0.65(0.84)$ between zero and three misleading claims

174 about nicotine safety.

175 *Industry belief indices*

176   Participants indicated how true they believed three positive and three negative statements

177 about tobacco companies to be using a four-point scale from completely false to completely true.

178 In general, participants were more likely to believe that negative statements were either mostly

179 or completely true including that companies use candy flavors to lure young people (77.84%),

180 spread false research about the safety of their products (74.57%), and that politicians take money

181 from tobacco companies to oppose regulations (80%). However, a substantial portion of

182 respondents believed positive statements were either mostly or completely true as well including

183 that tobacco companies were honest about the safety of their products (46.20%), are part of the

184   solution to ending smoking (39%), and that they do good things for the community like donate to

185   charity (48.90%). Summative indices were created for the number of positive M(SD)=0.99(1.01)

186   and negative M(SD)=1.86(1.06) beliefs about the tobacco industry that participants reported to

187   be either "mostly" or "completely true".

Analysis

189   Analyses were conducted using STATA v15. Ordinal logistic regression models with

190   robust standard errors were used to calculate odds ratios and 95% confidence intervals for the

191   association between social media platform use and recall and belief indices and for the

192   association between recall and belief indices and tobacco industry beliefs. Analyses also

193   included age, dummy codes for female, non-Hispanic Black, Hispanic, a high school

194   diploma/GED or lower education, and current EC use.

RESULTS

196   *Social media use and recall and belief in distorted science*

197   Table 2 presents odds ratios and 95% confidence intervals for ordinal logistic regression

198   models. COVID-19-related distorted science recall was significantly less likely among female

199   participants, but more likely among Black participants and those who used ECs. Greater Twitter

200   use was associated with higher odds of recalling distorted science about nicotine and COVID-19.

201   Belief in distorted science about nicotine and COVID-19 followed a similar trend. Female

202   participants were less likely to believe these claims while Black participants or those who used

203   ECs were more likely to believe them. Finally, greater use of both Twitter and YouTube were

204   associated with higher likelihood of believing these claims while greater Reddit use was

205   associated with lower likelihood of believing them. For distorted science about nicotine in

206   general, female participants were less likely to recall or believe these claims. Black participants

207 were more likely to believe these claims, however recall failed to reach significance. EC users

208 were more likely to recall and believe these claims while lower education participants were more

209 likely to believe them, but not to recall exposure to them in the last year. Although TikTok and

210 Twitter approached significance in predicting belief in claims related to nicotine in general, none

211 of the social media platforms reached significance for either recall or belief in these claims.

212 *Recall and belief in misinformation and tobacco industry beliefs*

213 Table 3 presents odds ratios and 95% confidence intervals for ordinal logistic regression

214 models. Current EC use was associated with more positive beliefs and less negative beliefs about

215 the tobacco industry. Moreover, less educated participants held less negative beliefs while

216 Hispanic participants were more likely to hold negative beliefs. Recall and belief in claims

217 distorting science of nicotine in general and belief in claims distorting science about nicotine and

218 COVID-19 were associated with more positive beliefs about the tobacco industry. Recall of

219 distorted science related to nicotine and COVID-19 approached significance in the same

220 direction. Only belief in distorted claims about nicotine in general was associated with more

221 negative beliefs about the tobacco industry.

DISCUSSION

223 The most important conclusion to draw from this research is that a substantial portion of

224 18–34 year-olds, a demographic far less likely to smoke combustible cigarettes than previous

225 generations [49], accept several erroneous claims about nicotine. In our sample, nearly 1 in 3

226 believed nicotine to be no more harmful than a cup of coffee, 1 in 4 believed nicotine to be

227 useful as a medical treatment for mood, attention, or memory disorders, and more than 1 in 8

228 believed that unlike CCs, nicotine from ECs is not addictive. While it is important to address

229 barriers to using effective cessation products like NRT, such as the overestimation of the dangers

230   of nicotine [11], these data suggest there is also substantial danger posed by the underestimation

231   of the dangers of nicotine. Young people who do not smoke, and in the case of those suffering

232   from mood or attention disorders may be at heightened risk of addiction [50], report both seeing

233   and believing demonstrably false or unsubstantiated information about nicotine safety that is

234   likely to encourage use [5] and result in lifelong addiction [31]. As the full extent of the known

235   harms from EC increase with more research [51], the continued dissemination of distorted

236   science about the safety of nicotine poses a sizeable long-term risk to public health.

237   The second important conclusion drawn from this work is that social media plays a

238   complex role in the current information environment. The often cited "infodemic" [52] of false

239   and misleading information spreading online encompasses COVID-19 [34, 53], ECs [54, 55]and

240   the intersection of the two [43]. However, false and misleading information comes varies from

241   unintentionally incorrect misinformation to intentionally deceitful disinformation [56]. Distorted

242   science exemplified in this study by the extrapolation of published scientific findings to support

243   unsubstantiated claims about a prospective therapeutic role of nicotine during the COVID-19

244   pandemic were recalled and believed more among more frequent users of Twitter and YouTube,

245   but less among frequent users of Reddit. These findings suggest that the different affordances of

246   specific social media platforms likely have different implications for not only spreading but also

247   correcting problematic information. The lack of traditional media gatekeepers on platforms like

248   YouTube and Twitter may allow misleading interpretations of these scientific studies to spread

249   unchecked [32, 57]. Meanwhile, the moderated forums or subreddits encouraging lengthy

250   discussions on Reddit may facilitate a user-base that is more informed than social media

251   platforms with restrictive character limits and a lack of formal moderation [58]. Previous

252   research suggesting many users view Reddit as a trusted source of actionable health information

13

253   [58, 59] suggests Reddit may have utility in disseminating correct information to counter

254   distorted science and other forms of mis and disinformation. Thus, although complicit in the

255   dissemination of distorted science about ECs and nicotine, social media may also offer a crucial

256   tool in reducing the impact of such information.

257   Finally, our finding that the tobacco industry's reputation is likely improved by the

258   spread of distorted science has distinct regulatory implications. The prevalence of positive

259   beliefs related to the tobacco industry's role in ending smoking, donating to charity, and that

260   nearly half of our sample (46%) believed that the tobacco industry was honest about the effects

261   of their products indicates that 18–34-year-old's are increasingly ambivalent about the role of the

262   tobacco industry in society. Unsubstantiated information about potentially therapeutic effects of

263   nicotine, framing ECs and other mass-marketed nicotine products as tools for "harm reduction,"

264   and efforts to distance nicotine from cigarettes in favor of likening nicotine use to caffeine from

265   a cup of coffee mirror old strategies used by tobacco companies to promote CCs [60]. For

266   example, one ad from Bidi stick states "a bidi stick a day keeps the pulmonologist away," [61]

267   conflating the potential reduced harm with switching from CCs to ECs with objectively false

268   claims of pulmonary benefits of using the product. The tobacco industry continues to spend

269   significantly on corporate social responsibility campaigns [62, 63] and strategically promote

270   products as environmentally friendly [63, 64] or their brands as charitable [65]. Intervention

271   strategies highlighting deception and manipulation by the tobacco industry have been among the

272   most effective strategies for deterring tobacco use [66]. By positioning ECs as the necessary

273   antidote to CCs, the tobacco industry is able to leverage distorted science and other forms of

274   misinformation to mobilize public support against regulation of ECs; potentially leveraging their

275   own past deception to permit unchecked promotion of ECs to a generation of non-smokers.

14

276   A crucial reason to monitor the spread of distorted science and other forms of

277 misinformation about nicotine on social media is that beliefs about nicotine are associated with

278 individual behavior, notably nicotine product curiosity, susceptibility, and use [5]. However, this

279 research focuses on the relationship between distorted science and industry attitudes because

280 efforts intended to mobilize political opposition to regulation on social media exemplified by

281 hashtags like #wevapewevote or #flavorssavelives often rely on misinformation [67]. Such

282 misinformation is problematic beyond the scope of behavior, as favorable public opinion is

283 integral to the success of tobacco control policies [68-70]. There is substantial evidence

284 supporting the problematic influence of misinformation on behavior in the context of nicotine

285 and tobacco [4, 8, 9, 71]. However, future research should more closely examine the specific

286 effects of distorted science on individual behavior as well.

287 *Limitations*

288   These data offer evidence of associations between self-reported social media use, beliefs,

289 and recall in a convenience sample. Thus, inferences about causality or effect sizes at a

290 population level are limited. However, our 18-34-year-old sample oversampling EC users

291 examines a key demographic subject to the influence of misinformation on tobacco regulation.

292 Though our estimates likely differ from general population parameters, this study provides

293 robust evidence that young adult EC users are more likely to recall and believe misinformation

294 about the effects of the products they use. Moreover, despite limitations regarding the

295 directionality of these relationships, this study provides robust evidence that social media can

296 play both a positive and negative role in disseminating and dispelling problematic information.

297 In addition to experimental designs better equipped to assess causality, future research should

298 examine not only how social media spreads misinformation, but also how the affordances of

15

299 some social media platforms can potentially be leveraged to correct and reduce the spread of

300 misinformation.

301   This research is also limited with respect to measurement. Self-reported measurements of

302 social media use are limited [72]. We followed best practice recommendations in breaking down

303 use by platform and adding specificity in assessing checking, posting, and commenting.

304 However, there are still inherent limitations regarding how accurately people recall and report

305 social media use which undoubtedly affect our results. To compensate for this limitation, we

306 adopted a conservative approach in including all of the social media platforms in the same

307 model, essentially controlling for use of all social media when estimating the odds ratio of any

308 single platform. As a result, non-significant findings for misinformation on Facebook (for

309 example) should not be interpreted as suggesting such information does not exist on Facebook,

310 but rather that Reddit, Youtube, and Twitter, which were significant, are of higher priority with

311 regards to the dissemination of such information among this demographic. Future research using

312 unobtrusive measures like logs from big data sources are needed.

313 *Conclusions*

314   Public understanding of the health impact of nicotine is currently mired by uncertainty.

315 Although there is currently no significant evidence supporting therapeutic benefits of nicotine

316 use, misinformation ostensibly backed by "science" is being disseminated on social media and

317 potentially facilitating good will towards the tobacco industry. In light of a long-documented

318 history of interfering in the scientific process and disseminating misinformation about its

319 products, the role of the tobacco industry in disseminating this information merits close

320 monitoring and significant countering messaging.

321

AUTHOR CONTRIBUTIONS

NS conceptualized the project with guidance and oversight from BS. NS and EK developed the survey instrument. NS completed the analysis. NS developed the manuscript with assistance from EK, JB and BS. All coauthors reviewed and revised the final draft.

COMPETING INTERESTS

Authors have declared no conflicts of interest.

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DATA AVAILABILITY

Data used in this study is housed at Truth Initiative and is not publicly available. Any inquiries can be directed to the first author.

ETHICS APPROVAL STATEMENT

This study was determined exempt from review by a private review board, Advarra IRB, (Pro00053405), as the research was conducted at a non-profit organization unaffiliated with an institution. The study was determined exempt in accordance with the Department of Health and Human Services regulations found at 45 CFR 46.104(d)(2). Specifically, as the information collected from these adult participants could not be used to personally identify them or present an undue risk by way of their responses.

17

REFERENCES

341 **REFERENCES**

342 [1]   Czoli CD, Fong GT, Mays D, *et al.* How do consumers perceive differences in risk across

343 nicotine products? A review of relative risk perceptions across smokeless tobacco, e-cigarettes,

344 nicotine replacement therapy and combustible cigarettes. *Tobacco Control* 2017;**26**(e1):e49.

345 [2]   Hajek P, Phillips-Waller A, Przulj D, *et al.* A Randomized Trial of E-Cigarettes versus

346 Nicotine-Replacement Therapy. *New England Journal of Medicine* 2019;**380**(7):629-637.

347 [3]   Soneji SS, Sung H-Y, Primack BA, *et al.* Quantifying population-level health benefits

348 and harms of e-cigarette use in the United States. *PLOS ONE* 2018;**13**(3):e0193328.

349 [4]   Luk TT, Zhao S, Weng X, *et al.* Exposure to health misinformation about COVID-19 and

350 increased tobacco and alcohol use: a population-based survey in Hong Kong. *Tobacco Control*

351 2020:tobaccocontrol-2020-055960.

352 [5]   Villanti AC, Naud S, West JC, *et al.* Prevalence and correlates of nicotine and nicotine

353 product perceptions in U.S. young adults, 2016. *Addictive Behaviors* 2019;**98**:106020.

354 [6]   Schillo B, Boonn A, Arendt M, *et al.* Educating the public and lawmakers about tobacco

355 industry interference. *Tob Induc Dis* 2021;**19**:4-4.

356 [7]   McInerney JD, Dougherty MJ. Abusing science. *FASEB BioAdvances* 2020;**2**(10):587-

357 595.

358 [8]   Chou W-YS, Oh A, Klein WMP. Addressing Health-Related Misinformation on Social

359 Media. *JAMA* 2018;**320**(23):2417-2418.

360 [9]   Tan ASL, Bigman CA. Misinformation About Commercial Tobacco Products on Social

361 Media—Implications and Research Opportunities for Reducing Tobacco-Related Health

362 Disparities. *American Journal of Public Health* 2020;**110**(S3):S281-S283.

363   [10]   Dewhirst T. Co-optation of harm reduction by Big Tobacco. *Tobacco Control*

364   2020:tobaccocontrol-2020-056059.

365   [11]   Shi R, Feldman R, Liu J*, et al.* The Dilemma of Correcting Nicotine Misperceptions:

366   Nicotine Replacement Therapy versus Electronic Cigarettes. *Health Communication* 2020:1-11.

367   [12]   Wackowski OA, Delnevo CD. Young Adults' Risk Perceptions of Various Tobacco

368   Products Relative to Cigarettes: Results From the National Young Adult Health Survey. *Health

369   Education & Behavior* 2015;**43**(3):328-336.

370   [13]   Steinberg MB, Bover Manderski MT, Wackowski OA*, et al.* Nicotine Risk

371   Misperception Among US Physicians. *Journal of general internal medicine* 2020.

372   [14]   Pacek LR, Rass O, Johnson MW. Knowledge about nicotine among HIV-positive

373   smokers: Implications for tobacco regulatory science policy. *Addictive Behaviors* 2017;**65**:81-86.

374   [15]   Patel D, Peiper N, Rodu B. Perceptions of the health risks related to cigarettes and

375   nicotine among university faculty. *Addiction Research & Theory* 2013;**21**(2):154-159.

376   [16]   Biebert A. You Don't Know Nicotine. 2020.

377   [17]   Norcia A. Why Are Smokers Being Hospitalized Less Often From Coronavirus? *VICE*

378   2020.

379   [18]   Hair EC, Bennett M, Sheen E*, et al.* Examining perceptions about IQOS heated tobacco

380   product: consumer studies in Japan and Switzerland. *Tobacco Control* 2018;**27**(Suppl 1):s70.

381   [19]   Robichaud MO, Seidenberg AB, Byron MJ. Tobacco companies introduce 'tobacco-free'

382   nicotine pouches. *Tobacco Control* 2020;**29**(e1):e145.

383   [20]   Sears CG, Walker KL, Hart JL*, et al.* Clean, cheap, convenient: promotion of electronic

384   cigarettes on YouTube. *Tobacco prevention cessation* 2017;**3**.

19

385   [21]   Lappas AS, Tzortzi AS, Konstantinidi EM*, et al.* Short-term respiratory effects of e-

386   cigarettes in healthy individuals and smokers with asthma. *Respirology* 2018;**23**(3):291-297.

387   [22]   Miyashita L, Foley G. E-cigarettes and respiratory health: the latest evidence. *The*

388   *Journal of Physiology* 2020;**598**(22):5027-5038.

389   [23]   Heeschen C, Jang JJ, Weis M*, et al.* Nicotine stimulates angiogenesis and promotes

390   tumor growth and atherosclerosis. *Nature Medicine* 2001;**7**(7):833-839.

391   [24]   Morris Pamela B, Ference Brian A, Jahangir E*, et al.* Cardiovascular Effects of Exposure

392   to Cigarette Smoke and Electronic Cigarettes. *Journal of the American College of Cardiology*

393   2015;**66**(12):1378-1391.

394   [25]   Nordskog BK, Blixt AD, Morgan WT*, et al.* Matrix-degrading and pro-inflammatory

395   changes in human vascular endothelial cells exposed to cigarette smoke condensate.

396   *Cardiovascular Toxicology* 2003;**3**(2):101-117.

397   [26]   Rejali M, Rejali AR, Zhang L*, et al.* Effects of nicotine on the cardiovascular system.

398   *Vascular Disease Prevention* 2005;**2**(2):135-144.

399   [27]   Bruin JE, Gerstein HC, Holloway AC. Long-Term Consequences of Fetal and Neonatal

400   Nicotine Exposure: A Critical Review. *Toxicological Sciences* 2010;**116**(2):364-374.

401   [28]   Dwyer JB, Broide RS, Leslie FM. Nicotine and brain development. *Birth Defects*

402   *Research Part C: Embryo Today: Reviews* 2008;**84**(1):30-44.

403   [29]   Slotkin TA, Skavicus S, Card J*, et al.* Developmental Neurotoxicity of Tobacco Smoke

404   Directed Toward Cholinergic and Serotonergic Systems: More Than Just Nicotine. *Toxicological*

405   *Sciences* 2015;**147**(1):178-189.

406   [30]   Smith RF, McDonald CG, Bergstrom HC, *et al.* Adolescent nicotine induces persisting

407   changes in development of neural connectivity. *Neuroscience & Biobehavioral Reviews*

408   2015;**55**:432-443.

409   [31]   Benowitz NL. Emerging Nicotine Delivery Products. Implications for Public Health.

410   *Annals of the American Thoracic Society* 2014;**11**(2):231-235.

411   [32]   Albarracin D, Shavitt S. Attitudes and Attitude Change. *Annual Review of Psychology*

412   2018;**69**(1):299-327.

413   [33]   Soule EK, Mayne S, Snipes W, *et al.* Impacts of COVID-19 on Electronic Cigarette

414   Purchasing, Use and Related Behaviors. *International Journal of Environmental Research and*

415   *Public Health* 2020;**17**(18).

416   [34]   Zhou C, Xiu H, Wang Y, *et al.* Characterizing the dissemination of misinformation on

417   social media in health emergencies: An empirical study based on COVID-19. *Information*

418   *Processing & Management* 2021;**58**(4):102554.

419   [35]   Farsalinos K, Barbouni A, Niaura R. Systematic review of the prevalence of current

420   smoking among hospitalized COVID-19 patients in China: could nicotine be a therapeutic

421   option? *Internal and Emergency Medicine* 2020;**15**(5):845-852.

422   [36]   Farsalinos K, Barbouni A, Poulas K, *et al.* Current smoking, former smoking, and

423   adverse outcome among hospitalized COVID-19 patients: a systematic review and meta-

424   analysis. *Therapeutic advances in chronic disease* 2020;**11**:2040622320935765.

425   [37]   Farsalinos K, Barbouni A, Niaura R. Smoking, vaping and hospitalization for COVID-19.

426   *Qeios* 2020.

427   [38]   Changeux J-P, Amoura Z, Rey FA, *et al.* A nicotinic hypothesis for Covid-19 with

428   preventive and therapeutic implications. *Comptes Rendus Biolgies* 2020;**343**(1):33-39.

21

429   [39]   Gülsen A, Yigitbas BA, Uslu B, *et al.* The Effect of Smoking on COVID-19 Symptom

430   Severity: Systematic Review and Meta-Analysis. *Pulmonary medicine* 2020;**2020**:7590207.

431   [40]   Karanasos A, Aznaouridis K, Latsios G, *et al.* Impact of smoking status on disease

432   severity and mortality of hospitalized patients with COVID-19 infection: a systematic review and

433   meta-analysis. *Nicotine Tobacco Research* 2020.

434   [41]   Patanavanich R, Glantz SA. Smoking is associated with COVID-19 progression: a meta-

435   analysis. *Nicotine Tobacco Research* 2020;**22**(9):1653-1656.

436   [42]   Gupta AK, Nethan ST, Mehrotra R. Tobacco use as a well-recognized cause of severe

437   COVID-19 manifestations. *Respiratory Medicine* 2021;**176**:106233.

438   [43]   Kavuluru R, Noh J, Rose SW. Twitter Discourse on Nicotine as Potential Prophylactic or

439   Therapeutic for COVID-19. *medRxiv* 2021:2021.2001.2005.21249284.

440   [44]   Kwon M, Park E. Perceptions and sentiments about electronic cigarettes on social media

441   platforms: systematic review. *JMIR Public Health Surveillance* 2020;**6**(1):e13673.

442   [45]   Lazard AJ, Saffer AJ, Wilcox GB, *et al.* E-cigarette social media messages: a text mining

443   analysis of marketing and consumer conversations on Twitter. *JMIR Public Health Surveillance*

444   2016;**2**(2):e6551.

445   [46]   Majmundar A, Moran MB. For or Against Tobacco Control: Sponsored Tobacco

446   Advocacy Messages on Facebook and Instagram. *Nicotine & Tobacco Research* 2021.

447   [47]   Trifiro BM, Gerson J. Social Media Usage Patterns: Research Note Regarding the Lack

448   of Universal Validated Measures for Active and Passive Use. *Social Media + Society*

449   2019;**5**(2):2056305119848743.

450   [48]   Robertson OH, Bigg E, Puck TT, *et al.* The bactericidal action of propylene glycol vapor

451   on microorganisms suspended in air. I. *J Exp Med* 1942;**75**(6):593-610.

452   [49]   Miech R, Leventhal A, Johnston L, *et al.* Trends in Use and Perceptions of Nicotine

453   Vaping Among US Youth From 2017 to 2020. *JAMA Pediatrics* 2021;**175**(2):185-190.

454   [50]   Mitchell JT, Weisner TS, Jensen PS, *et al.* How Substance Users With ADHD Perceive

455   the Relationship Between Substance Use and Emotional Functioning. *Journal of Attention*

456   *Disorders* 2017;**22**(9_suppl):49S-60S.

457   [51]   Xian S, Chen Y. E-cigarette users are associated with asthma disease: A meta-analysis.

458   *The Clinical Respiratory Journal* 2021;**15**(5):457-466.

459   [52]   Zarocostas J. How to fight an infodemic. *The Lancet* 2020;**395**(10225):676.

460   [53]   Kearney MD, Chiang SC, Massey PM. The Twitter origins and evolution of the COVID-

461   19 "plandemic" conspiracy theory. *Harvard Kennedy School Misinformation Review* 2020;**1**(3).

462   [54]   Chen E, Lerman K, Ferrara E. Tracking social media discourse about the covid-19

463   pandemic: Development of a public coronavirus twitter data set. *JMIR Public Health*

464   *Surveillance* 2020;**6**(2):e19273.

465   [55]   Collins L, Glasser AM, Abudayyeh H, *et al.* E-Cigarette Marketing and Communication:

466   How E-Cigarette Companies Market E-Cigarettes and the Public Engages with E-cigarette

467   Information. *Nicotine & Tobacco Research* 2019;**21**(1):14-24.

468   [56]   Vraga EK, Bode L. Defining Misinformation and Understanding its Bounded Nature:

469   Using Expertise and Evidence for Describing Misinformation. *Political Communication*

470   2020;**37**(1):136-144.

471   [57]   Allem J-P, Dormanesh A, Majmundar A, *et al.* Topics of Nicotine-Related Discussions

472   on Twitter: Infoveillance Study. *J Med Internet Res* 2021;**23**(6):e25579.

23

473   [58]   Record RA, Silberman WR, Santiago JE*, et al.* I Sought It, I Reddit: Examining Health

474   Information Engagement Behaviors among Reddit Users. *Journal of Health Communication*

475   2018;**23**(5):470-476.

476   [59]   Sowles SJ, Krauss MJ, Gebremedhn L*, et al.* "I feel like I've hit the bottom and have no

477   idea what to do": Supportive social networking on Reddit for individuals with a desire to quit

478   cannabis use. *Substance Abuse* 2017;**38**(4):477-482.

479   [60]   Henningfield JE, Rose CA, Zeller M. Tobacco industry litigation position on addiction:

480   continued dependence on past views. *Tobacco Control* 2006;**15**(suppl 4):iv27.

481   [61]   Campaign for Tobacco-Free Kids. Big Tobacco is Exploiting COVID-19 to Market its

482   Harmful Products. 2021 Date;Volume.

483   [62]   Hirschhorn N. Corporate social responsibility and the tobacco industry: hope or hype?

484   *Tobacco Control* 2004;**13**(4):447.

485   [63]   University of Bath. CSR Strategy Tobacco Tactics 2021 Date;Volume.

486   https://tobaccotactics.org/wiki/csr-strategy/.

487   [64]   Epperson AE, Lambin EF, Henriksen L*, et al.* Natural American Spirit's pro-environment

488   packaging and perceptions of reduced-harm cigarettes. *Preventive medicine* 2019;**126**:105782.

489   [65]   Fooks GJ, Gilmore AB. Corporate Philanthropy, Political Influence, and Health Policy.

490   *PLOS ONE* 2013;**8**(11):e80864.

491   [66]   Malone RE, Grundy Q, Bero LA. Tobacco industry denormalisation as a tobacco control

492   intervention: a review. *Tobacco Control* 2012;**21**(2):162.

493   [67]   Williams Kirkpatrick A. The spread of fake science: Lexical concreteness, proximity,

494   misinformation sharing, and the moderating role of subjective knowledge. *Public Understanding*

495   *of Science* 2020;**30**(1):55-74.

24

496   [68]   Boynton MH, Agans RP, Bowling JM*, et al.* Understanding how perceptions of tobacco

497   constituents and the FDA relate to effective and credible tobacco risk messaging: A national

498   phone survey of U.S. adults, 2014–2015. *BMC Public Health* 2016;**16**(1):516.

499   [69]   Kowitt SD, Goldstein AO, Schmidt AM*, et al.* Attitudes toward FDA regulation of newly

500   deemed tobacco products. *Tobacco Regulatory Science* 2017;**3**(4):504-515.

501   [70]   Schmidt AM, Kowitt SD, Myers AE*, et al.* Attitudes towards Potential New Tobacco

502   Control Regulations among U.S. Adults. *International Journal of Environmental Research and*

503   *Public Health* 2018;**15**(1).

504   [71]   Lee SJ, Sanders-Jackson A, Tan ASL. Effects of Current and Enhanced Tobacco

505   Corrective Messages on Smokers' Intention to Quit Smoking and Intention to Purchase

506   Cigarettes. *Nicotine & Tobacco Research* 2020;**22**(4):569-575.

507   [72]   de Vreese CH, Neijens P. Measuring Media Exposure in a Changing Communications

508   Environment. *Communication Methods and Measures* 2016;**10**(2-3):69-80.

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517 **TABLES:**

Table 1. Social media use by platform (N = 1225)

Platform	Have ever used	Use index[a] M	(SD)
Facebook	78.90%	1.73	(1.13)
Instagram	67.00%	1.41	(1.15)
Reddit	28.50%	0.50	(0.09)
Snapchat	51.90%	1.14	(1.22)
TikTok	45.10%	0.88	(1.10)
Twitter	40.60%	0.65	(0.89)
Youtube	80.90%	1.43	(0.98)

[a]Use index refers to an average of how often participants check, post, and respond to content on each platform on a four-point scale from anchored (0) "never" to (3) "often"

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TABLE 2. SOCIAL MEDIA PLATFORM USE PREDICTING RECALL AND BELIEF IN MISLEADING INFORMATION

	Recall distorted science COVID-19			Recall distorted science general			Believe distorted science COVID-19			Believe distorted science general		
	OR	*LLCI*	*ULCI*	*OR*	*LLCI*	*ULCI*	*OR*	*LLCI*	*ULCI*	*OR*	*LLCI*	*ULCI*
FEMALE	**0.45**	**(0.33**	**0.61)**	**0.67**	**(0.53**	**0.86)**	**0.50**	**(0.35**	**0.70)**	**0.63**	**(0.49**	**0.82)**
NON-HISPANIC BLACK	**2.00**	**(1.38**	**2.89)**	*1.33*	*(0.96*	*1.85)*	**2.46**	**(1.65**	**3.67)**	**1.44**	**(1.02**	**2.02)**
HISPANIC	1.33	(0.90	1.98)	1.30	(0.93	1.83)	1.09	(0.69	1.72)	0.90	(0.64	1.27)
HS[A]	1.07	(0.78	1.46)	1.19	(0.94	1.50)	1.01	(0.72	1.41)	**1.31**	**(1.03**	**1.66)**
CURRENTECIG[B]	**1.73**	**(1.25**	**2.39)**	**1.64**	**(1.29**	**2.09)**	**1.91**	**(1.36**	**2.67)**	**1.96**	**(1.54**	**2.50)**
AGE	1.00	(0.96	1.03)	**0.97**	**(0.94**	**0.99)**	0.99	(0.95	1.02)	1.00	(0.97	1.02)
FACEBOOK	0.98	(0.84	1.14)	1.10	(0.97	1.23)	1.06	(0.91	1.24)	1.08	(0.96	1.22)
INSTAGRAM	1.01	(0.86	1.19)	1.00	(0.88	1.12)	0.98	(0.82	1.17)	0.99	(0.87	1.12)
REDDIT	0.86	(0.72	1.04)	1.06	(0.93	1.22)	**0.72**	**(0.59**	**0.88)**	0.92	(0.80	1.06)
SNAPCHAT	1.00	(0.87	1.16)	0.94	(0.85	1.05)	1.00	(0.86	1.16)	1.03	(0.92	1.15)
TIKTOK	1.11	(0.95	1.29)	1.05	(0.93	1.18)	0.97	(0.82	1.14)	*1.11*	*(0.98*	*1.25)*
TWITTER	**1.21**	**(1.01**	**1.44)**	1.12	(0.97	1.28)	**1.26**	**(1.04**	**1.52)**	*1.16*	*(0.99*	*1.35)*
YOUTUBE	1.06	(0.89	1.26)	0.97	(0.85	1.11)	**1.32**	**(1.09**	**1.60)**	0.97	(0.85	1.11)

95% CONFIDENCE INTERVALS ARE CALCULATED USING ROBUST STANDARD ERRORS. ODDS RATIOS IN ITALICS ARE MARGINALLY SIGNIFICANT AT *P* < .1 WHILE THOSE IN BOLD ARE SIGNIFICANT AT *P* < .05. [A]DUMMY CODE FOR HAVING A HIGH SCHOOL DIPLOMA/GED OR LESS EDUCATION. [B]DUMMY CODE FOR HAVING USED E-CIGARETTE IN THE PAST 30 DAYS

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TABLE 3. RECALL AND ACCEPTANCE PREDICTING INDUSTRY BELIEFS

	Positive beliefs			Negative beliefs		
	OR	LLCI	ULCI	OR	LLCI	ULCI
FEMALE	1.05	(0.84	1.32)	1.13	(0.90	1.41)
NON-HISPANIC BLACK	1.02	(0.75	1.38)	1.07	(0.78	1.45)
HISPANIC	1.07	(0.77	1.48)	**1.44**	**(1.07**	**1.96)**
HS[A]	0.97	(0.78	1.21)	**0.63**	**(0.51**	**0.78)**
CURRENTECIG	**1.69**	**(1.35**	**2.12)**	**0.65**	**(0.52**	**0.82)**
AGE	1.02	(0.99	1.04)	0.99	(0.97	1.01)
RECALL DISTORTED SCIENCE COVID-19	1.20	(0.99	1.46)	0.98	(0.82	1.19)
RECALL DISTORTED SCIENCE GENERAL	**1.26**	**(1.07**	**1.47)**	0.99	(0.86	1.15)
BELIEVE DISTORTED SCIENCE COVID-19	**1.61**	**(1.34**	**1.95)**	1.05	(0.88	1.25)
BELIEVE DISTORTED SCIENCE GENERAL	**1.28**	**(1.09**	**1.50)**	**1.18**	**(1.02**	**1.35)**

95% CONFIDENCE INTERVALS ARE CALCULATED USING ROBUST STANDARD ERRORS. ODDS RATIOS IN ITALICS ARE MARGINALLY SIGNIFICANT AT $P < .1$ WHILE THOSE IN BOLD ARE SIGNIFICANT AT $P < .05$. [A]DUMMY CODE FOR HAVING A HIGH SCHOOL DIPLOMA/GED OR LESS EDUCATION [B]DUMMY CODE FOR HAVING USED E-CIGARETTE IN THE PAST 30 DAYS

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page	Line
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2	5
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2	2-25
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-7	48-125
Objectives	3	State specific objectives, including any prespecified hypotheses	7	122-125
Methods				
Study design	4	Present key elements of study design early in the paper	7	129-132
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7	129-135
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7	129-135
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10	143-187
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-10	143-187
Bias	9	Describe any efforts to address potential sources of bias	10	189-194
Study size	10	Explain how the study size was arrived at	7	129-135
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10	143-187
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10	189-194
		(*b*) Describe any methods used to examine subgroups and interactions		n/a
		(*c*) Explain how missing data were addressed	7	132-135
		(*d*) If applicable, describe analytical methods taking account of sampling strategy		n/a
		(*e*) Describe any sensitivity analyses		n/a
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7	132-135
		(b) Give reasons for non-participation at each stage		n/a
		(c) Consider use of a flow diagram		n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8	135-139
		(b) Indicate number of participants with missing data for each variable	7	132-

		of interest			135
Outcome data	15*	Report numbers of outcome events or summary measures		25	Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included		26-27	Table 2, Table 3
		(*b*) Report category boundaries when continuous variables were categorized			n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses			n/a
Discussion					
Key results	18	Summarise key results with reference to study objectives		11	223-228
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		14-15	289-314
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		15	315-321
Generalisability	21	Discuss the generalisability (external validity) of the study results		14	293-295
Other information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		16	330

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Charming e-cigarette users with distorted science: Examining the impact of misleading and false claims about nicotine on beliefs about the tobacco industry

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Charming e-cigarette users with distorted science: Examining the impact of misleading and false claims about nicotine on beliefs about the tobacco industry

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1 **Abstract**

2 **Objective.** To examine the role of social media in promoting recall and belief of distorted
3 science about nicotine and whether recall and belief in turn predict tobacco industry beliefs.
4

5 **Design.** Young adults 18-34 (*N=*1225) were surveyed cross-sectionally via online Qualtrics
6 panel. The survey assessed recall and belief in three claims about nicotine and COVID-19 and
7 three about nicotine in general followed by assessments of industry beliefs and use of social
8 media. Ordinal logistic regression with robust standard errors controlling for gender,
9 race/ethnicity, education, current e-cigarette use, and age was used to examine relationships
10 between variables.

11 **Results.** Twitter use was associated with higher odds of recall (OR=1.21,95% CI=1.01, 1.44)
12 and belief (OR=1.26,CI=1.04, 1.52) in COVID-19 specific distorted science. YouTube use was
13 associated with higher odds of believing COVID-19 specific distorted
14 science (OR=1.32,CI=1.09, 1.60). Reddit use was associated with lower odds
15 of believing COVID-19 specific distorted science (OR=0.72,CI=0.59, 0.88). Recall
16 (OR=1.26,CI=1.07, 1.47) and belief, (OR=1.28,CI=1.09, 1.50) in distorted science about nicotine
17 in general as well as belief in distorted science specific to COVID-19, (OR = 1.61,CI=1.34, 1.95)
18 were associated with more positive beliefs about the tobacco industry.
19 Belief distorted science about nicotine in general was associated with more negative beliefs
20 about the tobacco industry (OR=1.18,CI=1.02, 1.35).
21

22 **Conclusions.** Use of social media platforms may help to both spread and dispel distorted science
23 about nicotine. Addressing distorted science about nicotine is important, as it appears to be
24 associated with more favorable views of the tobacco industry which may erode public support
25 for effective regulation.
26

27

28 **What this paper adds:**
29 This study provides evidence of the role of social media in both disseminating as well as
30 dispelling misleading and potentially harmful misinformation about nicotine and suggests a role
31 for counter messaging. Additionally, addressing misinformation about nicotine is important, as it
32 appears to be associated with more favorable views of the tobacco industry which may erode
33 public support for effective regulation.
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Strengths and Limitations of this Study

- This study answers a novel and timely research question examining the distorted information environment surrounding nicotine and COVID-19.
- This study addresses an understudied area of tobacco control research, namely tobacco users' perceptions of the tobacco industry and how this may play into public perception of their products, and by extension, how they are regulated.
- This study is cross-sectional and thus causality cannot be identified from the analysis.
- This study sample is sufficient in size, however, it is not nationally representative and therefore limited in terms of external generalizability.

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Background

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49   Tobacco companies and some harm reduction advocates are promoting misleading and

50 even patently false claims about nicotine to frame efforts to regulate next generation nicotine

51 products as "anti-science." There is a legitimate need to differentiate the harmful consequences

52 of combustible cigarettes (CCs) from those of nicotine, as nicotine replacement therapy (NRT)

53 offers an evidence-based means for adults to quit smoking [1-3]. However, dissemination of

54 unsubstantiated claims about nicotine as a harmless stimulant or even a therapeutic method can

55 undermine public health by promoting the use of an addictive substance [4, 5]. The distortion of

56 science to fit a pro-tobacco narrative has a long history [6], and is now emerging to counter

57 evidence of the dangers associated with e-cigarette (EC) use [7]. The tobacco industry has seized

58 upon the reach of social media to disseminate distorted interpretations of science and

59 misinformation about ECs [8, 9], often through the lens of harm reduction [10]. The resulting

60 impact threatens to position tobacco companies in a more positive light as advocates for the

61 health of former smokers instead of purveyors and marketers of a harmful product, which in turn

62 threatens to undermine regulatory efforts. This research examines the potential role of social

63 media in disseminating distorted science about nicotine both in the context of the COVID-19

64 pandemic and in general, and the extent to which recall and belief in such information affects

65 beliefs about the tobacco industry.

66   Public understanding of the harms of nicotine are inextricably linked to harm perceptions

67 of CCs posing challenges to health communicators and practitioners [11]. The most recent

68 systematic literature review found that while most research showed relatively lower risk

69 perceptions for NRT and ECs compared to CCs, there remains confusion surrounding various

70 non-combustible products [1]. One study using data from the National Youth Tobacco Survey

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71 found that between 22-33% of respondents believed smokeless products were *more* dangerous

72 than CCs [12]. Another sample of young adults found that more than half of respondents

73 erroneously believed that nicotine was the cancer-causing agent in CCs, and that the risks of ECs

74 and NRT were equal to that of CCs [5]. Many of the same misperceptions were even held by a

75 majority of physicians [13]. These mistaken beliefs are problematic in that they can deter

76 evidenced-based NRT treatment that has been proven to help adult smokers quit [11, 14, 15].

77 However, EC advocates have seized on this confusion regarding the risks posed by nicotine to

78 conflate scientific support for the evidence-based benefits of NRT for helping adult smokers quit

79 with unsubstantiated and often distorted scientific claims about the safety of ECs [11]. Moreover,

80 media purporting to "uncover the truth behind nicotine" [16, 17], and broader efforts by tobacco

81 companies to market next generation products like ECs as safe alternatives to smoking, "tobacco

82 free," or "clean nicotine" [18-20] discount the inherent risks posed by nicotine, particularly to

83 youth and young adults, threatening to addict new users for life.

84   The distortion of scientific evidence has many consequences from information pollution

85 to the normalization of tobacco industry behavior. However, those who hold more antagonistic

86 views of the tobacco industry, wherein their actions are "denormalized," are more likely to

87 support policy regulating the industry [21]. Thus, the tobacco industry's attempts to market their

88 products as safe have the potential to undermine regulatory efforts [21].

89   Although nicotine is not responsible for many of the most well-known consequences of

90 smoking [22-24], nicotine is an addictive substance with strong potential for lifelong abuse [25],

91 may have adverse consequences on neural development [26-29], and though evidence is limited,

92 may pose additional risks to cardiovascular health [30-33]. The societal consequences of the

93 widespread belief that nicotine is harmless threatens to expand nicotine addiction far beyond

94   current levels driven by smoking, as beliefs about nicotine predict product use [5]. Recent

95   research suggests that social media has a high volume of problematic information about nicotine

96   and nicotine products [9]. Thus, it is important to examine the prevalence and potential effects of

97   such information, particularly on EC users to whom much of this information is targeted [34,

98   35].

99   The ambiguity surrounding COVID-19 has made it a common topic of misinformation

100 [36], particularly with respect to the effects of nicotine. One prominent example is based on a

101 review of clinical data in Wuhan Province, China showing a significantly lower prevalence of

102 smokers among patients admitted to ICUs for COVID-19 in the early months of the pandemic

103 [37, 38]. These findings prompted an editorial [39] and the registration of clinical trials testing

104 the hypothesis that nicotine may prevent infection and progression of COVID-19 [40]. While the

105 clinical trials have not yet concluded, research conducted since does not support any therapeutic

106 or prophylactic benefits of nicotine on COVID-19 [40]. In fact, in addition to smoking increasing

107 odds of disease progression and severe symptoms [41-43], a recent systematic review strongly

108 suggests that nicotine, including ECs and smokeless products, are a likely risk factor for

109 infection and progression of COVID-19 [44]. Although more research is needed to make

110 definitive claims about the effects of nicotine, there is currently no evidence supporting a

111 therapeutic use for nicotine with respect to COVID-19. Despite the lack of supporting evidence

112 and significant evidence to the contrary, an analysis of Twitter discourse identified a substantial

113 presence of content related to prevention or treatment of COVID-19 with nicotine [45].

114   Whether a deliberate effort by EC advocates or a product of online discourse with

115 minimal moderation, the dissemination of distorted science about nicotine on social media poses

116 a barrier to public health. Researchers have identified a variety of potential impacts of such

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117 information among EC users including bulk buying and increased usage [35]. Additionally, the

118 dissemination of information distorting the science of nicotine safety is likely to directly

119 undermine efforts to regulate the industry by creating more favorable views of ECs and the

120 companies who manufacture them. The most recent review of the literature suggests EC-related

121 content on social media tends to be favorable to EC use [46]. Moreover, analysis of social media

122 posts suggests an environment hostile to regulation [47] with a significant presence of sponsored

123 industry advocacy messaging [48]. The dissemination of distorted science positioning regulatory

124 efforts in opposition to public health threatens to further deceive the public regarding the safety

125 of nicotine and ECs [7]. The evidence to date highlights a need to examine the extent to which

126 distorted science about nicotine is disseminated on social media and its potential impact on

127 tobacco industry attitudes. Specifically, this work investigates the extent to which use of specific

128 social media platforms are associated with recall and belief in distorted science about nicotine.

129 We also aim to investigate the relationship between beliefs about the tobacco industry and recall

130 and belief in distorted science about nicotine.

131 **METHODS**

132 **Data Collection**

133 *Online Panel Survey*

134 We contracted with Qualtrics to recruit N=1225 participants ages 18-34 for a survey,

135 fielded June 4-June 11, 2021, to examine the relationship between exposure to and belief in

136 distorted science about nicotine in general and in the context of COVID-19, social media use,

137 and tobacco industry attitudes. An initial sample of N=2088 people consented to participate in

138 the study. Of those, n=495 failed an attention check asking to select a specific response, n=90

139 were removed for other quality control reasons (e.g. straight line responding), and n=278 were

140 removed for incomplete response sets leaving a final sample of N=1225. Participants were a

141 convenience sample and were aged 18-34 (M(SD)=26.95(4.85), 40.8% male, 70.27% white, with

142 39.39% reporting a high school diploma/GED or lower education. We oversampled for current

143 EC users (59.76%) with 75.27% reporting having ever used an ECs and having used ECs

144 products an average of 11.97 (SD=11.89) days in the last month.

145 *Patient and Public Involvement*

146 No patients or public were involved in the development of this research.

147 **Measures**

148 *Social media use*

149   Consistent with the literature, we assessed active (e.g. posting), passive (e.g. scrolling),

150 and social (e.g. commenting) elements of social media use [49]. Participants first indicated

151 whether they used several social media platforms. For each platform, a use index was calculated

152 based on the average of three items: whether the participant 1) checks content, 2) posts content,

153 and 3) responds to comments on each platform rarely (1), sometimes (2), or often (3). Table 1

154 provides summary statistics for both the percentage of our sample who used each platform as

155 well as the average amount of use.

156 *Recall and belief of distorted science indices*

157   COVID-19 related. Recall and belief indices for distorted science related to COVID-19

158 were calculated based on responses to three specific claims. The first claim that smokers are less

159 likely to be hospitalized for COVID-19 was related to the early review cited above and was

160 recalled by 12.53% with 11.65% believing it was either probably or definitely true. Claim two

161 represented the conclusions drawn by that study and the hypothesis then tested in future research

162 that "nicotine prevents the virus that causes COVID-19 from infecting cells" and was recalled by

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163 10.35% and believed by 9.35%. Finally, the third claim that "chemicals in vaping liquid (e.g.

164 propylene glycol) sterilize the air to protect from COVID infection" represents a

165 misappropriation of a very old study [50] that was promoted as evidence to support EC use

166 during the pandemic. Similar to the previous claims, 10.78% recalled while 9.47% believed it

167 was probably or definitely true. Summative indices were calculated for each participant with

168 higher values indicating a given respondent recalled $M(SD)=0.33(0.74)$ and believed

169 $M(SD)=0.30(0.72)$ between zero and three misleading scientific claims.

170   <u>General nicotine</u>. Recall and belief in three claims about nicotine safety were assessed in

171 the same manner as above. Participants indicated whether they recalled and believed three

172 statements that have been promoted in either popular media or advertising for ECs: "Nicotine is

173 only addictive when smoked from a cigarette" was recalled by 14.02% and believed by 13.29%.

174 "Nicotine by itself is no more harmful than caffeine from a cup of coffee" was recalled by

175 31.09% and believed by 29.02%. Finally, "Nicotine is useful as a medical treatment for people

176 with mood, attention, or memory disorders" was recalled by 20.79% and believed by 22.66%.

177 Summative indices were calculated for each participant. A given respondent recalled

178 $M(SD)=0.66(0.83)$ and believed $M(SD)=0.65(0.84)$ between zero and three misleading claims

179 about nicotine safety.

180 *Industry belief indices*

181   Participants indicated how true they believed three positive and three negative statements

182 about tobacco companies to be using a four-point scale from completely false to completely true.

183 In general, participants were more likely to believe that negative statements were either mostly

184 or completely true including that companies use candy flavors to lure young people (77.84%),

185 spread false research about the safety of their products (74.57%), and that politicians take money

186   from tobacco companies to oppose regulations (80%). However, a substantial portion of

187   respondents believed positive statements were either mostly or completely true as well including

188   that tobacco companies were honest about the safety of their products (46.20%), are part of the

189   solution to ending smoking (39%), and that they do good things for the community like donate to

190   charity (48.90%). Summative indices were created for the number of positive M(SD)=0.99(1.01)

191   and negative M(SD)=1.86(1.06) beliefs about the tobacco industry that participants reported to

192   be either "mostly" or "completely true".

Analysis

194   Analyses were conducted using STATA v15. Ordinal logistic regression models with

195   robust standard errors were used to calculate odds ratios and 95% confidence intervals for the

196   association between social media platform use and recall and belief indices and for the

197   association between recall and belief indices and tobacco industry beliefs. Analyses also

198   included age, dummy codes for female, non-Hispanic Black, Hispanic, a high school

199   diploma/GED or lower education, and current EC use.

RESULTS

201   *Social media use and recall and belief in distorted science*

202   Table 2 presents odds ratios and 95% confidence intervals for ordinal logistic regression

203   models. COVID-19-related distorted science recall was significantly less likely among female

204   participants, but more likely among Black participants and those who used ECs. Greater Twitter

205   use was associated with higher odds of recalling distorted science about nicotine and COVID-19.

206   Belief in distorted science about nicotine and COVID-19 followed a similar trend. Female

207   participants were less likely to believe these claims while Black participants or those who used

208   ECs were more likely to believe them. Finally, greater use of both Twitter and YouTube were

209 associated with higher likelihood of believing these claims while greater Reddit use was

210 associated with lower likelihood of believing them. For distorted science about nicotine in

211 general, female participants were less likely to recall or believe these claims. Black participants

212 were more likely to believe these claims, however recall failed to reach significance. EC users

213 were more likely to recall and believe these claims while lower education participants were more

214 likely to believe them, but not to recall exposure to them in the last year. Although TikTok and

215 Twitter approached significance in predicting belief in claims related to nicotine in general, none

216 of the social media platforms reached significance for either recall or belief in these claims.

217 *Recall and belief in misinformation and tobacco industry beliefs*

218 Table 3 presents odds ratios and 95% confidence intervals for ordinal logistic regression

219 models. Current EC use was associated with more positive beliefs and less negative beliefs about

220 the tobacco industry. Moreover, less educated participants held less negative beliefs while

221 Hispanic participants were more likely to hold negative beliefs. Recall and belief in claims

222 distorting science of nicotine in general and belief in claims distorting science about nicotine and

223 COVID-19 were associated with more positive beliefs about the tobacco industry. Recall of

224 distorted science related to nicotine and COVID-19 approached significance in the same

225 direction. Only belief in distorted claims about nicotine in general was associated with more

226 negative beliefs about the tobacco industry.

227 **DISCUSSION**

228 The most important conclusion to draw from this research is that a substantial portion of

229 18–34 year-olds, a demographic far less likely to smoke combustible cigarettes than previous

230 generations [51], accept several erroneous claims about nicotine. In our sample, nearly 1 in 3

231 believed nicotine to be no more harmful than a cup of coffee, 1 in 4 believed nicotine to be

232 useful as a medical treatment for mood, attention, or memory disorders, and more than 1 in 8

233 believed that unlike CCs, nicotine from ECs is not addictive. While it is important to address

234 barriers to using effective cessation products like NRT, such as the overestimation of the dangers

235 of nicotine [11], these data suggest there is also substantial danger posed by the underestimation

236 of the dangers of nicotine. Young people who do not smoke, and in the case of those suffering

237 from mood or attention disorders may be at heightened risk of addiction [52], report both seeing

238 and believing demonstrably false or unsubstantiated information about nicotine safety that is

239 likely to encourage use [5] and result in lifelong addiction [25]. As the full extent of the known

240 harms from ECs increase with more research [53], the continued dissemination of distorted

241 science about the safety of nicotine poses a sizeable long-term risk to public health.

242 Public attitudes surrounding nicotine are still intrinsically tied to CCs. However, the

243 proliferation of alternative nicotine products like ECs will inevitably lead to youth and young

244 adult perceptions of nicotine divorced from the connotation of smoking. As such perceptions

245 evolve, future research must examine the influence of both formal and informal information

246 channels on attitudes and beliefs about nicotine in its growing variety of forms.

247 The second important conclusion drawn from this work is that social media plays a

248 complex role in the current information environment. The often cited "infodemic" [54] of false

249 and misleading information spreading online encompasses COVID-19 [36, 55], ECs [56, 57] and

250 the intersection of the two [45]. However, false and misleading information varies from

251 unintentionally incorrect misinformation to intentionally deceitful disinformation [58]. Distorted

252 science exemplified in this study by the extrapolation of published scientific findings to support

253 unsubstantiated claims about a prospective therapeutic role of nicotine during the COVID-19

254 pandemic were recalled and believed more among more frequent users of Twitter and YouTube,

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255 but less among frequent users of Reddit. These findings suggest that the different characteristics

256 of specific social media platforms that enable and influence the ways users of such platforms

257 share and encounter information, i.e. technological affordances [59], may offer a useful

258 framework for examining the role of social media in both spreading and correcting problematic

259 information. The lack of traditional media gatekeepers on platforms like YouTube and Twitter

260 may allow misleading interpretations of these scientific studies to spread unchecked [34, 60].

261 Meanwhile, the moderated forums or subreddits encouraging lengthy discussions on Reddit may

262 facilitate a user-base that is more informed than social media platforms with restrictive character

263 limits and a lack of formal moderation [61]. Previous research suggesting many users view

264 Reddit as a trusted source of actionable health information [61, 62] suggests Reddit may have

265 utility in disseminating correct information to counter distorted science and other forms of mis

266 and disinformation. Thus, although complicit in the dissemination of distorted science about ECs

267 and nicotine, social media may also offer a crucial tool in reducing the impact of such

268 information. That said, it is also important to note that Reddit and Twitter were not used as

269 frequently as other platforms amongst our study participants. This is reflective of the greater

270 social media environment wherein Twitter and Reddit, although used more among younger

271 generations than older adults, fall behind leaders YouTube, Facebook and Instagram in

272 popularity [63].

273 It is also important to note that, when controlling for demographic differences, we

274 identified that non-Hispanic Black participants had higher odds of recall and belief of

275 misinformation and Hispanic participants had higher odds of reporting negative industry beliefs.

276 We hesitate to hypothesize a basis for these trends due to the small sample of racial and ethnic

277 minority participants surveyed in our convenience sample. That said, these findings emphasize

278 the need for further research into understanding the racial and ethnic differences in the impact of

279 misinformation.

280   Finally, our finding that the tobacco industry's reputation is likely improved by the

281 spread of distorted science has distinct regulatory implications. The prevalence of positive

282 beliefs related to the tobacco industry's role in ending smoking, donating to charity, and that

283 nearly half of our sample (46%) believed that the tobacco industry was honest about the effects

284 of their products indicates that 18–34-year-olds are increasingly ambivalent about the role of the

285 tobacco industry in society. Unsubstantiated information about potentially therapeutic effects of

286 nicotine, framing ECs and other mass-marketed nicotine products as tools for "harm reduction,"

287 and efforts to distance nicotine from cigarettes in favor of likening nicotine use to caffeine from

288 a cup of coffee mirror old strategies used by tobacco companies to promote CCs [64]. For

289 example, one ad from Bidi stick states "a bidi stick a day keeps the pulmonologist away," [65]

290 conflating the potential reduced harm with switching from CCs to ECs with objectively false

291 claims of pulmonary benefits of using the product. The tobacco industry continues to spend

292 significantly on corporate social responsibility campaigns [66, 67] and strategically promote

293 products as environmentally friendly [67, 68] or their brands as charitable [69]. Intervention

294 strategies highlighting deception and manipulation by the tobacco industry have been among the

295 most effective strategies for deterring tobacco use [70]. By positioning ECs as the necessary

296 antidote to CCs, the tobacco industry uses distorted science and other forms of misinformation to

297 mobilize public support against regulation of ECs; potentially leveraging their own past

298 deception to permit unchecked promotion of ECs to a generation of non-smokers. Previous

299 research supports the use of news literacy campaigns and expert correction as strategies for

300 combatting misinformation. Moreover, in addition to the importance of monitoring the channels

15

301 through which problematic information spreads to vulnerable subpopulations, the US Surgeon

302 General's report on health misinformation highlights the importance of "prebunking" to

303 inoculate the public to the sorts of misinformation they are likely to encounter [71, 72].

304　　　　A crucial reason to monitor the spread of distorted science and other forms of

305 misinformation about nicotine on social media is that beliefs about nicotine are associated with

306 individual behavior, notably nicotine product curiosity, susceptibility, and use [5]. However, this

307 research focuses on the relationship between distorted science and industry attitudes because

308 efforts intended to mobilize political opposition to regulation on social media exemplified by

309 hashtags like #wevapewevote or #flavorssavelives often rely on misinformation [73]. Such

310 misinformation is problematic beyond the scope of behavior, as favorable public opinion is

311 integral to the success of tobacco control policies [74-76]. It appears that more antagonistic

312 views of the tobacco industry are tied to greater support for tobacco industry regulation [21].

313 There is substantial evidence supporting the problematic influence of misinformation on

314 behavior in the context of nicotine and tobacco [4, 8, 9, 77]. However, future research should

315 more closely examine the specific effects of distorted science on individual behavior as well.

316 *Limitations*

317　　　　These data offer evidence of associations between self-reported social media use, beliefs,

318 and recall in a convenience sample. Although we provide evidence of an association between use

319 of specific social media platforms and recall and belief in mis and disinformation, we do not

320 assess whether exposure to such information occurred on social media in general or any specific

321 platform. Thus, while the proliferation of misinformation on social media is a well-documented

322 phenomenon [35, 45], our data do not provide definitive evidence that misinformation is more

323   likely to spread on Twitter versus Reddit, but rather that Twitter users are more likely to recall

324   and believe such information, whereas Reddit users are less likely.

325   As with any survey, inferences about causality or effect sizes at a population level are

326   limited. Moreover, methods used to maintain data quality for online opt-in surveys such as the

327   attention checks we used may pose further limitations to studying the people most susceptible to

328   misinformation. Although it is best practice not to over-interpret responses from respondents

329   screened out by such attention checks, we note that recall and belief of distorted science was

330   significantly higher among those who failed them. Thus, methodological approaches to studying

331   misinformation should account for the fact that the same inattentiveness we use to screen

332   responses for surveys may also screen out misinformation-susceptible participants. Though our

333   estimates likely differ from general population parameters, this study provides robust evidence

334   that young adult EC users are more likely to recall and believe misinformation about the effects

335   of the products they use. In addition to experimental designs better equipped to assess causality,

336   future research should examine not only how social media spreads misinformation, but also how

337   the characteristics that differ between platforms influence patterns of dissemination across

338   platforms.

339   Additionally, self-reported measurements of social media use are limited [78]. We

340   followed best practice recommendations in social media use measurement, however, there

341   remain inherent limitations regarding how accurately people recall and report social media use

342   which undoubtedly affect our results. To compensate for this limitation, we adopted a

343   conservative approach in including all of the social media platforms in the same model,

344   essentially controlling for use of all social media when estimating the odds ratio of any single

345   platform. As a result, non-significant findings for misinformation on Facebook (for example)

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346   should not be interpreted as suggesting such information does not exist on Facebook, but rather

347   that Reddit, Youtube, and Twitter, which were significant, are of higher priority with regards to

348   the dissemination of such information among this demographic. Future research using

349   unobtrusive measures like logs from big data sources are needed.

350   *Conclusions*

351   Public understanding of the health impact of nicotine is currently mired by uncertainty.

352   Although there is currently no significant evidence supporting therapeutic benefits of nicotine

353   use, misinformation ostensibly backed by "science" is being disseminated on social media and

354   potentially facilitating good will towards the tobacco industry. In light of a long-documented

355   history of interfering in the scientific process and disseminating misinformation about its

356   products, the role of the tobacco industry in disseminating this information merits close

357   monitoring, significant countering messaging, and proactive inoculation against potentially

358   harmful narratives.

359

AUTHOR CONTRIBUTIONS

361   NS conceptualized the project with guidance and oversight from BS. NS and EK developed the

362   survey instrument. NS completed the analysis. NS developed the manuscript with assistance

363   from EK, JB and BS. All coauthors reviewed and revised the final draft.

COMPETING INTERESTS

365   Authors have declared no conflicts of interest.

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368 not-for-profit sectors.

DATA AVAILABILITY

370 Data used in this study is housed at Truth Initiative and is not publicly available. Any inquiries

371 can be directed to the first author.

ETHICS APPROVAL STATEMENT

373 This study was determined exempt from review by a private review board, Advarra IRB,

374 (Pro00053405), as the research was conducted at a non-profit organization unaffiliated with an

375 institution. The study was determined exempt in accordance with the Department of Health and

376 Human Services regulations found at 45 CFR 46.104(d)(2). Specifically, as the information

377 collected from these adult participants could not be used to personally identify them or present

378 an undue risk by way of their responses.

19

REFERENCES

[1]   Czoli CD, Fong GT, Mays D, *et al.* How do consumers perceive differences in risk across nicotine products? A review of relative risk perceptions across smokeless tobacco, e-cigarettes, nicotine replacement therapy and combustible cigarettes. *Tobacco Control* 2017;**26**(e1):e49.

[2]   Hajek P, Phillips-Waller A, Przulj D, *et al.* A Randomized Trial of E-Cigarettes versus Nicotine-Replacement Therapy. *New England Journal of Medicine* 2019;**380**(7):629-637.

[3]   Soneji SS, Sung H-Y, Primack BA, *et al.* Quantifying population-level health benefits and harms of e-cigarette use in the United States. *PLOS ONE* 2018;**13**(3):e0193328.

[4]   Luk TT, Zhao S, Weng X, *et al.* Exposure to health misinformation about COVID-19 and increased tobacco and alcohol use: a population-based survey in Hong Kong. *Tobacco Control* 2020:tobaccocontrol-2020-055960.

[5]   Villanti AC, Naud S, West JC, *et al.* Prevalence and correlates of nicotine and nicotine product perceptions in U.S. young adults, 2016. *Addictive Behaviors* 2019;**98**:106020.

[6]   Schillo B, Boonn A, Arendt M, *et al.* Educating the public and lawmakers about tobacco industry interference. *Tob Induc Dis* 2021;**19**:4-4.

[7]   McInerney JD, Dougherty MJ. Abusing science. *FASEB BioAdvances* 2020;**2**(10):587-595.

[8]   Chou W-YS, Oh A, Klein WMP. Addressing Health-Related Misinformation on Social Media. *JAMA* 2018;**320**(23):2417-2418.

[9]   Tan ASL, Bigman CA. Misinformation About Commercial Tobacco Products on Social Media—Implications and Research Opportunities for Reducing Tobacco-Related Health Disparities. *American Journal of Public Health* 2020;**110**(S3):S281-S283.

[10]   Dewhirst T. Co-optation of harm reduction by Big Tobacco. *Tobacco Control* 2020:tobaccocontrol-2020-056059.

[11]   Shi R, Feldman R, Liu J, *et al.* The Dilemma of Correcting Nicotine Misperceptions: Nicotine Replacement Therapy versus Electronic Cigarettes. *Health Communication* 2020:1-11.

[12]   Wackowski OA, Delnevo CD. Young Adults' Risk Perceptions of Various Tobacco Products Relative to Cigarettes: Results From the National Young Adult Health Survey. *Health Education & Behavior* 2015;**43**(3):328-336.

[13]   Steinberg MB, Bover Manderski MT, Wackowski OA, *et al.* Nicotine Risk Misperception Among US Physicians. *Journal of general internal medicine* 2020.

[14]   Pacek LR, Rass O, Johnson MW. Knowledge about nicotine among HIV-positive smokers: Implications for tobacco regulatory science policy. *Addictive Behaviors* 2017;**65**:81-86.

[15]   Patel D, Peiper N, Rodu B. Perceptions of the health risks related to cigarettes and nicotine among university faculty. *Addiction Research & Theory* 2013;**21**(2):154-159.

[16]   Biebert A. You Don't Know Nicotine. 2020.

[17]   Norcia A. Why Are Smokers Being Hospitalized Less Often From Coronavirus? *VICE* 2020.

[18]   Hair EC, Bennett M, Sheen E, *et al.* Examining perceptions about IQOS heated tobacco product: consumer studies in Japan and Switzerland. *Tobacco Control* 2018;**27**(Suppl 1):s70.

[19]   Robichaud MO, Seidenberg AB, Byron MJ. Tobacco companies introduce 'tobacco-free' nicotine pouches. *Tobacco Control* 2020;**29**(e1):e145.

[20]   Sears CG, Walker KL, Hart JL, *et al.* Clean, cheap, convenient: promotion of electronic cigarettes on YouTube. *Tobacco prevention cessation* 2017;**3**.

[21]   Chen J, Ho SY, Leung LT, *et al.* Adolescent Support for Tobacco Control Policies and Associations with Tobacco Denormalization Beliefs and Harm Perceptions. *International Journal of Environmental Research and Public Health* 2019;**16**(1).

[22]   Lappas AS, Tzortzi AS, Konstantinidi EM, *et al.* Short-term respiratory effects of e-cigarettes in healthy individuals and smokers with asthma. *Respirology* 2018;**23**(3):291-297.

[23]   Miyashita L, Foley G. E-cigarettes and respiratory health: the latest evidence. *The Journal of Physiology* 2020;**598**(22):5027-5038.

428 [24] National Academies of Sciences E, Medicine. Public Health Consequences of E-Cigarettes.
429 Washington, DC: The National Academies Press 2018.
430 [25] Benowitz NL. Emerging Nicotine Delivery Products. Implications for Public Health. *Annals of*
431 *the American Thoracic Society* 2014;**11**(2):231-235.
432 [26] Bruin JE, Gerstein HC, Holloway AC. Long-Term Consequences of Fetal and Neonatal Nicotine
433 Exposure: A Critical Review. *Toxicological Sciences* 2010;**116**(2):364-374.
434 [27] Dwyer JB, Broide RS, Leslie FM. Nicotine and brain development. *Birth Defects Research Part*
435 *C: Embryo Today: Reviews* 2008;**84**(1):30-44.
436 [28] Slotkin TA, Skavicus S, Card J*, et al.* Developmental Neurotoxicity of Tobacco Smoke Directed
437 Toward Cholinergic and Serotonergic Systems: More Than Just Nicotine. *Toxicological Sciences*
438 2015;**147**(1):178-189.
439 [29] Smith RF, McDonald CG, Bergstrom HC*, et al.* Adolescent nicotine induces persisting changes
440 in development of neural connectivity. *Neuroscience & Biobehavioral Reviews* 2015;**55**:432-443.
441 [30] Heeschen C, Jang JJ, Weis M*, et al.* Nicotine stimulates angiogenesis and promotes tumor growth
442 and atherosclerosis. *Nature Medicine* 2001;**7**(7):833-839.
443 [31] Morris Pamela B, Ference Brian A, Jahangir E*, et al.* Cardiovascular Effects of Exposure to
444 Cigarette Smoke and Electronic Cigarettes. *Journal of the American College of Cardiology*
445 2015;**66**(12):1378-1391.
446 [32] Nordskog BK, Blixt AD, Morgan WT*, et al.* Matrix-degrading and pro-inflammatory changes in
447 human vascular endothelial cells exposed to cigarette smoke condensate. *Cardiovascular Toxicology*
448 2003;**3**(2):101-117.
449 [33] Rejali M, Rejali AR, Zhang L*, et al.* Effects of nicotine on the cardiovascular system. *Vascular*
450 *Disease Prevention* 2005;**2**(2):135-144.
451 [34] Albarracin D, Shavitt S. Attitudes and Attitude Change. *Annual Review of Psychology*
452 2018;**69**(1):299-327.
453 [35] Soule EK, Mayne S, Snipes W*, et al.* Impacts of COVID-19 on Electronic Cigarette Purchasing,
454 Use and Related Behaviors. *International Journal of Environmental Research and Public Health*
455 2020;**17**(18).
456 [36] Zhou C, Xiu H, Wang Y*, et al.* Characterizing the dissemination of misinformation on social
457 media in health emergencies: An empirical study based on COVID-19. *Information Processing &*
458 *Management* 2021;**58**(4):102554.
459 [37] Farsalinos K, Barbouni A, Niaura R. Systematic review of the prevalence of current smoking
460 among hospitalized COVID-19 patients in China: could nicotine be a therapeutic option? *Internal and*
461 *Emergency Medicine* 2020;**15**(5):845-852.
462 [38] Farsalinos K, Barbouni A, Poulas K*, et al.* Current smoking, former smoking, and adverse
463 outcome among hospitalized COVID-19 patients: a systematic review and meta-analysis. *Therapeutic*
464 *advances in chronic disease* 2020;**11**:2040622320935765.
465 [39] Farsalinos K, Barbouni A, Niaura R. Smoking, vaping and hospitalization for COVID-19. *Qeios*
466 2020.
467 [40] Changeux J-P, Amoura Z, Rey FA*, et al.* A nicotinic hypothesis for Covid-19 with preventive and
468 therapeutic implications. *Comptes Rendus Biolgies* 2020;**343**(1):33-39.
469 [41] Gülsen A, Yigitbas BA, Uslu B*, et al.* The Effect of Smoking on COVID-19 Symptom Severity:
470 Systematic Review and Meta-Analysis. *Pulmonary medicine* 2020;**2020**:7590207.
471 [42] Karanasos A, Aznaouridis K, Latsios G*, et al.* Impact of smoking status on disease severity and
472 mortality of hospitalized patients with COVID-19 infection: a systematic review and meta-analysis.
473 *Nicotine Tobacco Research* 2020.
474 [43] Patanavanich R, Glantz SA. Smoking is associated with COVID-19 progression: a meta-analysis.
475 *Nicotine Tobacco Research* 2020;**22**(9):1653-1656.
476 [44] Gupta AK, Nethan ST, Mehrotra R. Tobacco use as a well-recognized cause of severe COVID-19
477 manifestations. *Respiratory Medicine* 2021;**176**:106233.

21

478   [45]   Kavuluru R, Noh J, Rose SW. Twitter Discourse on Nicotine as Potential Prophylactic or
479   Therapeutic for COVID-19. *medRxiv* 2021:2021.001.2005.21249284.
480   [46]   Kwon M, Park E. Perceptions and sentiments about electronic cigarettes on social media
481   platforms: systematic review. *JMIR Public Health Surveillance* 2020;**6**(1):e13673.
482   [47]   Lazard AJ, Saffer AJ, Wilcox GB*, et al.* E-cigarette social media messages: a text mining analysis
483   of marketing and consumer conversations on Twitter. *JMIR Public Health Surveillance* 2016;**2**(2):e6551.
484   [48]   Majmundar A, Moran MB. For or Against Tobacco Control: Sponsored Tobacco Advocacy
485   Messages on Facebook and Instagram. *Nicotine & Tobacco Research* 2021.
486   [49]   Trifiro BM, Gerson J. Social Media Usage Patterns: Research Note Regarding the Lack of
487   Universal Validated Measures for Active and Passive Use. *Social Media + Society*
488   2019;**5**(2):2056305119848743.
489   [50]   Robertson OH, Bigg E, Puck TT*, et al.* THE BACTERICIDAL ACTION OF PROPYLENE
490   GLYCOL VAPOR ON MICROORGANISMS SUSPENDED IN AIR. I. *J Exp Med* 1942;**75**(6):593-610.
491   [51]   Miech R, Leventhal A, Johnston L*, et al.* Trends in Use and Perceptions of Nicotine Vaping
492   Among US Youth From 2017 to 2020. *JAMA Pediatrics* 2021;**175**(2):185-190.
493   [52]   Mitchell JT, Weisner TS, Jensen PS*, et al.* How Substance Users With ADHD Perceive the
494   Relationship Between Substance Use and Emotional Functioning. *Journal of Attention Disorders*
495   2017;**22**(9_suppl):49S-60S.
496   [53]   Xian S, Chen Y. E-cigarette users are associated with asthma disease: A meta-analysis. *The
497   Clinical Respiratory Journal* 2021;**15**(5):457-466.
498   [54]   Zarocostas J. How to fight an infodemic. *The Lancet* 2020;**395**(10225):676.
499   [55]   Kearney MD, Chiang SC, Massey PM. The Twitter origins and evolution of the COVID-19
500   "plandemic" conspiracy theory. *Harvard Kennedy School Misinformation Review* 2020;**1**(3).
501   [56]   Chen E, Lerman K, Ferrara E. Tracking social media discourse about the covid-19 pandemic:
502   Development of a public coronavirus twitter data set. *JMIR Public Health Surveillance* 2020;**6**(2):e19273.
503   [57]   Collins L, Glasser AM, Abudayyeh H*, et al.* E-Cigarette Marketing and Communication: How E-
504   Cigarette Companies Market E-Cigarettes and the Public Engages with E-cigarette Information. *Nicotine
505   & Tobacco Research* 2019;**21**(1):14-24.
506   [58]   Vraga EK, Bode L. Defining Misinformation and Understanding its Bounded Nature: Using
507   Expertise and Evidence for Describing Misinformation. *Political Communication* 2020;**37**(1):136-144.
508   [59]   Leonardi PM, Nardi BA, Kallinikos J. Materiality and organizing: Social interaction in a
509   technological world: Oxford university press on demand 2012.
510   [60]   Allem J-P, Dormanesh A, Majmundar A*, et al.* Topics of Nicotine-Related Discussions on
511   Twitter: Infoveillance Study. *J Med Internet Res* 2021;**23**(6):e25579.
512   [61]   Record RA, Silberman WR, Santiago JE*, et al.* I Sought It, I Reddit: Examining Health
513   Information Engagement Behaviors among Reddit Users. *Journal of Health Communication*
514   2018;**23**(5):470-476.
515   [62]   Sowles SJ, Krauss MJ, Gebremedhn L*, et al.* "I feel like I've hit the bottom and have no idea what
516   to do": Supportive social networking on Reddit for individuals with a desire to quit cannabis use.
517   *Substance Abuse* 2017;**38**(4):477-482.
518   [63]   Auxier B, Anderson M. Social Media Use in 2021. Pew Research Center 2021.
519   [64]   Henningfield JE, Rose CA, Zeller M. Tobacco industry litigation position on addiction: continued
520   dependence on past views. *Tobacco Control* 2006;**15**(suppl 4):iv27.
521   [65]   Campaign for Tobacco-Free Kids. Big Tobacco is Exploiting COVID-19 to Market its Harmful
522   Products. 2021 Date;Volume.
523   [66]   Hirschhorn N. Corporate social responsibility and the tobacco industry: hope or hype? *Tobacco
524   Control* 2004;**13**(4):447.
525   [67]   University of Bath. CSR Strategy Tobacco Tactics 2021 Date;Volume.
526   https://tobaccotactics.org/wiki/csr-strategy/.
527   [68]   Epperson AE, Lambin EF, Henriksen L*, et al.* Natural American Spirit's pro-environment
528   packaging and perceptions of reduced-harm cigarettes. *Preventive medicine* 2019;**126**:105782.

22

529   [69]   Fooks GJ, Gilmore AB. Corporate Philanthropy, Political Influence, and Health Policy. *PLOS*
530   *ONE* 2013;**8**(11):e80864.
531   [70]   Malone RE, Grundy Q, Bero LA. Tobacco industry denormalisation as a tobacco control
532   intervention: a review. *Tobacco Control* 2012;**21**(2):162.
533   [71]   Donovan J. Concrete Recommendations for Cutting Through Misinformation During the
534   COVID-19 Pandemic. *American Journal of Public Health* 2020;**110**(S3):S286-S287.
535   [72]   Murthy VH. Confronting Health Misinformation: The U.S. Surgeon General's Advisory on
536   Building a Healthy Information Environment. 2021.
537   [73]   Williams Kirkpatrick A. The spread of fake science: Lexical concreteness, proximity,
538   misinformation sharing, and the moderating role of subjective knowledge. *Public Understanding of*
539   *Science* 2020;**30**(1):55-74.
540   [74]   Boynton MH, Agans RP, Bowling JM*, et al.* Understanding how perceptions of tobacco
541   constituents and the FDA relate to effective and credible tobacco risk messaging: A national phone survey
542   of U.S. adults, 2014–2015. *BMC Public Health* 2016;**16**(1):516.
543   [75]   Kowitt SD, Goldstein AO, Schmidt AM*, et al.* Attitudes toward FDA regulation of newly deemed
544   tobacco products. *Tobacco Regulatory Science* 2017;**3**(4):504-515.
545   [76]   Schmidt AM, Kowitt SD, Myers AE*, et al.* Attitudes towards Potential New Tobacco Control
546   Regulations among U.S. Adults. *International Journal of Environmental Research and Public Health*
547   2018;**15**(1).
548   [77]   Lee SJ, Sanders-Jackson A, Tan ASL. Effects of Current and Enhanced Tobacco Corrective
549   Messages on Smokers' Intention to Quit Smoking and Intention to Purchase Cigarettes. *Nicotine &*
550   *Tobacco Research* 2020;**22**(4):569-575.
551   [78]   de Vreese CH, Neijens P. Measuring Media Exposure in a Changing Communications
552   Environment. *Communication Methods and Measures* 2016;**10**(2-3):69-80.

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561   **TABLES:**

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Table 1. Social media use by platform (N = 1225)

Platform	Have ever used	Use index[a]	
		M	(SD)
Facebook	78.90%	1.73	(1.13)
Instagram	67.00%	1.41	(1.15)
Reddit	28.50%	0.50	(0.09)
Snapchat	51.90%	1.14	(1.22)
TikTok	45.10%	0.88	(1.10)
Twitter	40.60%	0.65	(0.89)
Youtube	80.90%	1.43	(0.98)

[a]Use index refers to an average of how often participants check, post, and respond to content on each platform on a four-point scale from anchored (0) "never" to (3) "often"

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TABLE 2. SOCIAL MEDIA PLATFORM USE PREDICTING RECALL AND BELIEF IN MISLEADING INFORMATION

	Recall distorted science COVID-19			Recall distorted science general			Believe distorted science COVID-19			Believe distorted science general		
	OR	LLCI	ULCI	OR	LLCI	ULCI	OR	LLCI	ULCI	OR	LLCI	ULCI
FEMALE	**0.45**	**(0.33**	**0.61)**	**0.67**	**(0.53**	**0.86)**	**0.50**	**(0.35**	**0.70)**	**0.63**	**(0.49**	**0.82)**
NON-HISPANIC BLACK	**2.00**	**(1.38**	**2.89)**	*1.33*	*(0.96*	*1.85)*	**2.46**	**(1.65**	**3.67)**	**1.44**	**(1.02**	**2.02)**
HISPANIC	1.33	(0.90	1.98)	1.30	(0.93	1.83)	1.09	(0.69	1.72)	0.90	(0.64	1.27)
HS[A]	1.07	(0.78	1.46)	1.19	(0.94	1.50)	1.01	(0.72	1.41)	**1.31**	**(1.03**	**1.66)**
CURRENTECIG[B]	**1.73**	**(1.25**	**2.39)**	**1.64**	**(1.29**	**2.09)**	**1.91**	**(1.36**	**2.67)**	**1.96**	**(1.54**	**2.50)**
AGE	1.00	(0.96	1.03)	**0.97**	**(0.94**	**0.99)**	0.99	(0.95	1.02)	1.00	(0.97	1.02)
FACEBOOK	0.98	(0.84	1.14)	1.10	(0.97	1.23)	1.06	(0.91	1.24)	1.08	(0.96	1.22)
INSTAGRAM	1.01	(0.86	1.19)	1.00	(0.88	1.12)	0.98	(0.82	1.17)	0.99	(0.87	1.12)
REDDIT	0.86	(0.72	1.04)	1.06	(0.93	1.22)	**0.72**	**(0.59**	**0.88)**	0.92	(0.80	1.06)
SNAPCHAT	1.00	(0.87	1.16)	0.94	(0.85	1.05)	1.00	(0.86	1.16)	1.03	(0.92	1.15)
TIKTOK	1.11	(0.95	1.29)	1.05	(0.93	1.18)	0.97	(0.82	1.14)	*1.11*	*(0.98*	*1.25)*
TWITTER	**1.21**	**(1.01**	**1.44)**	1.12	(0.97	1.28)	**1.26**	**(1.04**	**1.52)**	*1.16*	*(0.99*	*1.35)*
YOUTUBE	1.06	(0.89	1.26)	0.97	(0.85	1.11)	**1.32**	**(1.09**	**1.60)**	0.97	(0.85	1.11)

95% CONFIDENCE INTERVALS ARE CALCULATED USING ROBUST STANDARD ERRORS. ODDS RATIOS IN ITALICS ARE MARGINALLY SIGNIFICANT AT *P* < .1 WHILE THOSE IN BOLD ARE SIGNIFICANT AT *P* < .05. [A]DUMMY CODE FOR HAVING A HIGH SCHOOL DIPLOMA/GED OR LESS EDUCATION. [B]DUMMY CODE FOR HAVING USED E-CIGARETTE IN THE PAST 30 DAYS

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TABLE 3. RECALL AND ACCEPTANCE PREDICTING INDUSTRY BELIEFS

	Positive beliefs			Negative beliefs		
	OR	LLCI	ULCI	OR	LLCI	ULCI
FEMALE	1.05	(0.84	1.32)	1.13	(0.90	1.41)
NON-HISPANIC BLACK	1.02	(0.75	1.38)	1.07	(0.78	1.45)
HISPANIC	1.07	(0.77	1.48)	**1.44**	**(1.07**	**1.96)**
HS[A]	0.97	(0.78	1.21)	**0.63**	**(0.51**	**0.78)**
CURRENTECIG	**1.69**	**(1.35**	**2.12)**	**0.65**	**(0.52**	**0.82)**
AGE	1.02	(0.99	1.04)	0.99	(0.97	1.01)
RECALL DISTORTED SCIENCE COVID-19	1.20	(0.99	1.46)	0.98	(0.82	1.19)
RECALL DISTORTED SCIENCE GENERAL	**1.26**	**(1.07**	**1.47)**	0.99	(0.86	1.15)
BELIEVE DISTORTED SCIENCE COVID-19	**1.61**	**(1.34**	**1.95)**	1.05	(0.88	1.25)
BELIEVE DISTORTED SCIENCE GENERAL	**1.28**	**(1.09**	**1.50)**	**1.18**	**(1.02**	**1.35)**

95% CONFIDENCE INTERVALS ARE CALCULATED USING ROBUST STANDARD ERRORS. ODDS RATIOS IN ITALICS ARE MARGINALLY SIGNIFICANT AT *P* < .1 WHILE THOSE IN BOLD ARE SIGNIFICANT AT *P* < .05. [A]DUMMY CODE FOR HAVING A HIGH SCHOOL DIPLOMA/GED OR LESS EDUCATION [B]DUMMY CODE FOR HAVING USED E-CIGARETTE IN THE PAST 30 DAYS

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page	Line
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2	5
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2	2-25
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-7	48-125
Objectives	3	State specific objectives, including any prespecified hypotheses	7	122-125
Methods				
Study design	4	Present key elements of study design early in the paper	7	129-132
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7	129-135
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7	129-135
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10	143-187
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-10	143-187
Bias	9	Describe any efforts to address potential sources of bias	10	189-194
Study size	10	Explain how the study size was arrived at	7	129-135
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10	143-187
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10	189-194
		(*b*) Describe any methods used to examine subgroups and interactions		n/a
		(*c*) Explain how missing data were addressed	7	132-135
		(*d*) If applicable, describe analytical methods taking account of sampling strategy		n/a
		(*e*) Describe any sensitivity analyses		n/a
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7	132-135
		(b) Give reasons for non-participation at each stage		n/a
		(c) Consider use of a flow diagram		n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8	135-139
		(b) Indicate number of participants with missing data for each variable	7	132-

			of interest		135
Outcome data	15*		Report numbers of outcome events or summary measures	25	Table 1
Main results	16		(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	26-27	Table 2, Table 3
			(*b*) Report category boundaries when continuous variables were categorized		n/a
			(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		n/a
Other analyses	17		Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses		n/a

Discussion

Key results	18	Summarise key results with reference to study objectives	11	223-228
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15	289-314
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15	315-321
Generalisability	21	Discuss the generalisability (external validity) of the study results	14	293-295

Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16	330

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Charming e-cigarette users with distorted science: A survey examining social media platform use, nicotine-related misinformation, and attitudes towards the tobacco industry

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Charming e-cigarette users with distorted science: A survey examining social media platform use, nicotine-related misinformation, and attitudes towards the tobacco industry

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Abstract

Objective. To examine the role of social media in promoting recall and belief of distorted science about nicotine and COVID-19 and whether recall and belief predict tobacco industry beliefs.

Design. Young adults 18-34 (*N*=1225) were surveyed cross-sectionally via online Qualtrics panel. The survey assessed recall and belief in three claims about nicotine and COVID-19 and three about nicotine in general followed by assessments of industry beliefs and use of social media. Ordinal logistic regression with robust standard errors controlling for gender, race/ethnicity, education, current e-cigarette use, and age was used to examine relationships between variables.

Results. Twitter use was associated with higher odds of recall (OR=1.21,95% CI=1.01, 1.44) and belief (OR=1.26,CI=1.04, 1.52) in COVID-19 specific distorted science. YouTube use was associated with higher odds of believing COVID-19 specific distorted science (OR=1.32,CI=1.09, 1.60). Reddit use was associated with lower odds of believing COVID-19 specific distorted science (OR=0.72,CI=0.59, 0.88). Recall (OR=1.26,CI=1.07, 1.47) and belief, (OR=1.28,CI=1.09, 1.50) in distorted science about nicotine in general as well as belief in distorted science specific to COVID-19, (OR = 1.61,CI=1.34, 1.95) were associated with more positive beliefs about the tobacco industry. Belief distorted science about nicotine in general was associated with more negative beliefs about the tobacco industry (OR=1.18,CI=1.02, 1.35).

Conclusions. Use of social media platforms may help to both spread and dispel distorted science about nicotine. Addressing distorted science about nicotine is important, as it appears to be associated with more favorable views of the tobacco industry which may erode public support for effective regulation.

3

Strengths and Limitations of this Study

- This study answers a novel and timely research question examining the distorted information environment surrounding nicotine and COVID-19.
- This study addresses an understudied area of tobacco control research, namely tobacco users' perceptions of the tobacco industry and how this may play into public perception of their products, and by extension, how they are regulated.
- This study is cross-sectional and thus causality cannot be identified from the analysis.
- This study sample is sufficient in size, however, it is not nationally representative and therefore limited in terms of external generalizability.

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Background

44   Tobacco companies and some harm reduction advocates are promoting misleading and

46 even patently false claims about nicotine to frame efforts to regulate next generation nicotine

47 products as "anti-science." There is a legitimate need to differentiate the harmful consequences

48 of combustible cigarettes (CCs) from those of nicotine, as nicotine replacement therapy (NRT)

49 offers an evidence-based means for adults to quit smoking [1-3]. However, dissemination of

50 unsubstantiated claims about nicotine as a harmless stimulant or even a therapeutic method can

51 undermine public health by promoting the use of an addictive substance [4, 5]. The distortion of

52 science to fit a pro-tobacco narrative has a long history [6], and is now emerging to counter

53 evidence of the dangers associated with e-cigarette (EC) use [7]. The tobacco industry has seized

54 upon the reach of social media to disseminate distorted interpretations of science and

55 misinformation about ECs [8, 9], often through the lens of harm reduction [10]. The resulting

56 impact threatens to position tobacco companies in a more positive light as advocates for the

57 health of former smokers instead of purveyors and marketers of a harmful product, which in turn

58 threatens to undermine regulatory efforts. This research examines the potential role of social

59 media in disseminating distorted science about nicotine both in the context of the COVID-19

60 pandemic and in general, and the extent to which recall and belief in such information affects

61 beliefs about the tobacco industry.

62   Public understanding of the harms of nicotine are inextricably linked to harm perceptions

63 of CCs posing challenges to health communicators and practitioners [11]. The most recent

64 systematic literature review found that while most research showed relatively lower risk

65 perceptions for NRT and ECs compared to CCs, there remains confusion surrounding various

66 non-combustible products [1]. One study using data from the National Youth Tobacco Survey

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67 found that between 22-33% of respondents believed smokeless products were *more* dangerous

68 than CCs [12]. Another sample of young adults found that more than half of respondents

69 erroneously believed that nicotine was the cancer-causing agent in CCs, and that the risks of ECs

70 and NRT were equal to that of CCs [5]. Many of the same misperceptions were even held by a

71 majority of physicians [13]. These mistaken beliefs are problematic in that they can deter

72 evidenced-based NRT treatment that has been proven to help adult smokers quit [11, 14, 15].

73 However, EC advocates have seized on this confusion regarding the risks posed by nicotine to

74 conflate scientific support for the evidence-based benefits of NRT for helping adult smokers quit

75 with unsubstantiated and often distorted scientific claims about the safety of ECs [11]. Moreover,

76 media purporting to "uncover the truth behind nicotine" [16, 17], and broader efforts by tobacco

77 companies to market next generation products like ECs as safe alternatives to smoking, "tobacco

78 free," or "clean nicotine" [18-20] discount the inherent risks posed by nicotine, particularly to

79 youth and young adults, threatening to addict new users for life.

80   The distortion of scientific evidence has many consequences from information pollution

81 to the normalization of tobacco industry behavior. However, those who hold more antagonistic

82 views of the tobacco industry, wherein their actions are "denormalized," are more likely to

83 support policy regulating the industry [21]. Thus, the tobacco industry's attempts to market their

84 products as safe have the potential to undermine regulatory efforts [21].

85   Although nicotine is not responsible for many of the most well-known consequences of

86 smoking [22-24], nicotine is an addictive substance with strong potential for lifelong abuse [25],

87 may have adverse consequences on neural development [26-29], and though evidence is limited,

88 may pose additional risks to cardiovascular health [30-33]. The societal consequences of the

89 widespread belief that nicotine is harmless threatens to expand nicotine addiction far beyond

90 current levels driven by smoking, as beliefs about nicotine predict product use [5]. Recent

91 research suggests that social media has a high volume of problematic information about nicotine

92 and nicotine products [9]. Thus, it is important to examine the prevalence and potential effects of

93 such information, particularly on EC users to whom much of this information is targeted [34,

94 35].

95   The ambiguity surrounding COVID-19 has made it a common topic of misinformation

96 [36], particularly with respect to the effects of nicotine. One prominent example is based on a

97 review of clinical data in Wuhan Province, China showing a significantly lower prevalence of

98 smokers among patients admitted to ICUs for COVID-19 in the early months of the pandemic

99 [37, 38]. These findings prompted an editorial [39] and the registration of clinical trials testing

100 the hypothesis that nicotine may prevent infection and progression of COVID-19 [40]. While the

101 clinical trials have not yet concluded, research conducted since does not support any therapeutic

102 or prophylactic benefits of nicotine on COVID-19 [40]. In fact, in addition to smoking increasing

103 odds of disease progression and severe symptoms [41-43], a recent systematic review strongly

104 suggests that nicotine, including ECs and smokeless products, are a likely risk factor for

105 infection and progression of COVID-19 [44]. Although more research is needed to make

106 definitive claims about the effects of nicotine, there is currently no evidence supporting a

107 therapeutic use for nicotine with respect to COVID-19. Despite the lack of supporting evidence

108 and significant evidence to the contrary, an analysis of Twitter discourse identified a substantial

109 presence of content related to prevention or treatment of COVID-19 with nicotine [45].

110   Whether a deliberate effort by EC advocates or a product of online discourse with

111 minimal moderation, the dissemination of distorted science about nicotine on social media poses

112 a barrier to public health. Researchers have identified a variety of potential impacts of such

7

113   information among EC users including bulk buying and increased usage [35]. Additionally, the

114   dissemination of information distorting the science of nicotine safety is likely to directly

115   undermine efforts to regulate the industry by creating more favorable views of ECs and the

116   companies who manufacture them. The most recent review of the literature suggests EC-related

117   content on social media tends to be favorable to EC use [46]. Moreover, analysis of social media

118   posts suggests an environment hostile to regulation [47] with a significant presence of sponsored

119   industry advocacy messaging [48]. The dissemination of distorted science positioning regulatory

120   efforts in opposition to public health threatens to further deceive the public regarding the safety

121   of nicotine and ECs [7]. The evidence to date highlights a need to examine the extent to which

122   distorted science about nicotine is disseminated on social media and its potential impact on

123   tobacco industry attitudes. Specifically, this work investigates the extent to which use of specific

124   social media platforms are associated with recall and belief in distorted science about nicotine.

125   We also aim to investigate the relationship between beliefs about the tobacco industry and recall

126   and belief in distorted science about nicotine.

127   **METHODS**

128   **Data Collection**

129   *Online Panel Survey*

130   We contracted with Qualtrics to recruit N=1225 participants ages 18-34 for a survey,

131   fielded June 4-June 11, 2021, to examine the relationship between exposure to and belief in

132   distorted science about nicotine in general and in the context of COVID-19, social media use,

133   and tobacco industry attitudes. An initial sample of N=2088 people consented to participate in

134   the study. Of those, n=495 failed an attention check asking to select a specific response, n=90

135   were removed for other quality control reasons (e.g. straight line responding), and n=278 were

136 removed for incomplete response sets leaving a final sample of N=1225. Participants were a

137 convenience sample and were aged 18-34 (M(SD)=26.95(4.85), 40.8% male, 70.27% white, with

138 39.39% reporting a high school diploma/GED or lower education. We oversampled for current

139 EC users (59.76%) with 75.27% reporting having ever used an ECs and having used ECs

140 products an average of 11.97 (SD=11.89) days in the last month.

141 *Patient and Public Involvement*

142 No patients or public were involved in the development of this research.

143 **Measures**

144 *Social media use*

145 Consistent with the literature, we assessed active (e.g. posting), passive (e.g. scrolling),

146 and social (e.g. commenting) elements of social media use [49]. Participants first indicated

147 whether they used several social media platforms. For each platform, a use index was calculated

148 based on the average of three items: whether the participant 1) checks content, 2) posts content,

149 and 3) responds to comments on each platform rarely (1), sometimes (2), or often (3). Table 1

150 provides summary statistics for both the percentage of our sample who used each platform as

151 well as the average amount of use.

152 *Recall and belief of distorted science indices*

153 COVID-19 related. Recall and belief indices for distorted science related to COVID-19

154 were calculated based on responses to three specific claims. The first claim that smokers are less

155 likely to be hospitalized for COVID-19 was related to the early review cited above and was

156 recalled by 12.53% with 11.65% believing it was either probably or definitely true. Claim two

157 represented the conclusions drawn by that study and the hypothesis then tested in future research

158 that "nicotine prevents the virus that causes COVID-19 from infecting cells" and was recalled by

159 10.35% and believed by 9.35%. Finally, the third claim that "chemicals in vaping liquid (e.g.

160 propylene glycol) sterilize the air to protect from COVID infection" represents a

161 misappropriation of a very old study [50] that was promoted as evidence to support EC use

162 during the pandemic. Similar to the previous claims, 10.78% recalled while 9.47% believed it

163 was probably or definitely true. Summative indices were calculated for each participant with

164 higher values indicating a given respondent recalled $M(SD)$=0.33(0.74) and believed

165 $M(SD)$=0.30(0.72) between zero and three misleading scientific claims.

166   General nicotine. Recall and belief in three claims about nicotine safety were assessed in

167 the same manner as above. Participants indicated whether they recalled and believed three

168 statements that have been promoted in either popular media or advertising for ECs: "Nicotine is

169 only addictive when smoked from a cigarette" was recalled by 14.02% and believed by 13.29%.

170 "Nicotine by itself is no more harmful than caffeine from a cup of coffee" was recalled by

171 31.09% and believed by 29.02%. Finally, "Nicotine is useful as a medical treatment for people

172 with mood, attention, or memory disorders" was recalled by 20.79% and believed by 22.66%.

173 Summative indices were calculated for each participant. A given respondent recalled

174 $M(SD)$=0.66(0.83) and believed $M(SD)$=0.65(0.84) between zero and three misleading claims

175 about nicotine safety.

176 *Industry belief indices*

177   Participants indicated how true they believed three positive and three negative statements

178 about tobacco companies to be using a four-point scale from completely false to completely true.

179 In general, participants were more likely to believe that negative statements were either mostly

180 or completely true including that companies use candy flavors to lure young people (77.84%),

181 spread false research about the safety of their products (74.57%), and that politicians take money

182   from tobacco companies to oppose regulations (80%). However, a substantial portion of

183   respondents believed positive statements were either mostly or completely true as well including

184   that tobacco companies were honest about the safety of their products (46.20%), are part of the

185   solution to ending smoking (39%), and that they do good things for the community like donate to

186   charity (48.90%). Summative indices were created for the number of positive M(SD)=0.99(1.01)

187   and negative M(SD)=1.86(1.06) beliefs about the tobacco industry that participants reported to

188   be either "mostly" or "completely true".

189   **Analysis**

190   Analyses were conducted using STATA v15. Ordinal logistic regression models with

191   robust standard errors were used to calculate odds ratios and 95% confidence intervals for the

192   association between social media platform use and recall and belief indices and for the

193   association between recall and belief indices and tobacco industry beliefs. Analyses also

194   included age, dummy codes for female, non-Hispanic Black, Hispanic, a high school

195   diploma/GED or lower education, and current EC use.

196   **RESULTS**

197   *Social media use and recall and belief in distorted science*

198   Table 2 presents odds ratios and 95% confidence intervals for ordinal logistic regression

199   models. COVID-19-related distorted science recall was significantly less likely among female

200   participants, but more likely among Black participants and those who used ECs. Greater Twitter

201   use was associated with higher odds of recalling distorted science about nicotine and COVID-19.

202   Belief in distorted science about nicotine and COVID-19 followed a similar trend. Female

203   participants were less likely to believe these claims while Black participants or those who used

204   ECs were more likely to believe them. Finally, greater use of both Twitter and YouTube were

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205   associated with higher likelihood of believing these claims while greater Reddit use was

206   associated with lower likelihood of believing them. For distorted science about nicotine in

207   general, female participants were less likely to recall or believe these claims. Black participants

208   were more likely to believe these claims, however recall failed to reach significance. EC users

209   were more likely to recall and believe these claims while lower education participants were more

210   likely to believe them, but not to recall exposure to them in the last year. Although TikTok and

211   Twitter approached significance in predicting belief in claims related to nicotine in general, none

212   of the social media platforms reached significance for either recall or belief in these claims.

213   *Recall and belief in misinformation and tobacco industry beliefs*

214   Table 3 presents odds ratios and 95% confidence intervals for ordinal logistic regression

215   models. Current EC use was associated with more positive beliefs and less negative beliefs about

216   the tobacco industry. Moreover, less educated participants held less negative beliefs while

217   Hispanic participants were more likely to hold negative beliefs. Recall and belief in claims

218   distorting science of nicotine in general and belief in claims distorting science about nicotine and

219   COVID-19 were associated with more positive beliefs about the tobacco industry. Recall of

220   distorted science related to nicotine and COVID-19 approached significance in the same

221   direction. Only belief in distorted claims about nicotine in general was associated with more

222   negative beliefs about the tobacco industry.

223   **DISCUSSION**

224   The most important conclusion to draw from this research is that a substantial portion of

225   18–34 year-olds, a demographic far less likely to smoke combustible cigarettes than previous

226   generations [51], accept several erroneous claims about nicotine. In our sample, nearly 1 in 3

227   believed nicotine to be no more harmful than a cup of coffee, 1 in 4 believed nicotine to be

228 useful as a medical treatment for mood, attention, or memory disorders, and more than 1 in 8

229 believed that unlike CCs, nicotine from ECs is not addictive. While it is important to address

230 barriers to using effective cessation products like NRT, such as the overestimation of the dangers

231 of nicotine [11], these data suggest there is also substantial danger posed by the underestimation

232 of the dangers of nicotine. Young people who do not smoke, and in the case of those suffering

233 from mood or attention disorders may be at heightened risk of addiction [52], report both seeing

234 and believing demonstrably false or unsubstantiated information about nicotine safety that is

235 likely to encourage use [5] and result in lifelong addiction [25]. As the full extent of the known

236 harms from ECs increase with more research [53], the continued dissemination of distorted

237 science about the safety of nicotine poses a sizeable long-term risk to public health.

238   Public attitudes surrounding nicotine are still intrinsically tied to CCs. However, the

239 proliferation of alternative nicotine products like ECs will inevitably lead to youth and young

240 adult perceptions of nicotine divorced from the connotation of smoking. As such perceptions

241 evolve, future research must examine the influence of both formal and informal information

242 channels on attitudes and beliefs about nicotine in its growing variety of forms.

243   The second important conclusion drawn from this work is that social media plays a

244 complex role in the current information environment. The often cited "infodemic" [54] of false

245 and misleading information spreading online encompasses COVID-19 [36, 55], ECs [56, 57] and

246 the intersection of the two [45]. However, false and misleading information varies from

247 unintentionally incorrect misinformation to intentionally deceitful disinformation [58]. Distorted

248 science exemplified in this study by the extrapolation of published scientific findings to support

249 unsubstantiated claims about a prospective therapeutic role of nicotine during the COVID-19

250 pandemic were recalled and believed more among more frequent users of Twitter and YouTube,

251 but less among frequent users of Reddit. These findings suggest that the different characteristics

252 of specific social media platforms that enable and influence the ways users of such platforms

253 share and encounter information, i.e. technological affordances [59], may offer a useful

254 framework for examining the role of social media in both spreading and correcting problematic

255 information. The lack of traditional media gatekeepers on platforms like YouTube and Twitter

256 may allow misleading interpretations of these scientific studies to spread unchecked [34, 60].

257 Meanwhile, the moderated forums or subreddits encouraging lengthy discussions on Reddit may

258 facilitate a user-base that is more informed than social media platforms with restrictive character

259 limits and a lack of formal moderation [61]. Previous research suggesting many users view

260 Reddit as a trusted source of actionable health information [61, 62] suggests Reddit may have

261 utility in disseminating correct information to counter distorted science and other forms of mis

262 and disinformation. Thus, although complicit in the dissemination of distorted science about ECs

263 and nicotine, social media may also offer a crucial tool in reducing the impact of such

264 information. That said, it is also important to note that Reddit and Twitter were not used as

265 frequently as other platforms amongst our study participants. This is reflective of the greater

266 social media environment wherein Twitter and Reddit, although used more among younger

267 generations than older adults, fall behind leaders YouTube, Facebook and Instagram in

268 popularity [63].

269   It is also important to note that, when controlling for demographic differences, we

270 identified that non-Hispanic Black participants had higher odds of recall and belief of

271 misinformation and Hispanic participants had higher odds of reporting negative industry beliefs.

272 We hesitate to hypothesize a basis for these trends due to the small sample of racial and ethnic

273 minority participants surveyed in our convenience sample. That said, these findings emphasize

274 the need for further research into understanding the racial and ethnic differences in the impact of

275 misinformation.

276   Finally, our finding that the tobacco industry's reputation is likely improved by the

277 spread of distorted science has distinct regulatory implications. The prevalence of positive

278 beliefs related to the tobacco industry's role in ending smoking, donating to charity, and that

279 nearly half of our sample (46%) believed that the tobacco industry was honest about the effects

280 of their products indicates that 18–34-year-olds are increasingly ambivalent about the role of the

281 tobacco industry in society. Unsubstantiated information about potentially therapeutic effects of

282 nicotine, framing ECs and other mass-marketed nicotine products as tools for "harm reduction,"

283 and efforts to distance nicotine from cigarettes in favor of likening nicotine use to caffeine from

284 a cup of coffee mirror old strategies used by tobacco companies to promote CCs [64]. For

285 example, one ad from Bidi stick states "a bidi stick a day keeps the pulmonologist away," [65]

286 conflating the potential reduced harm with switching from CCs to ECs with objectively false

287 claims of pulmonary benefits of using the product. The tobacco industry continues to spend

288 significantly on corporate social responsibility campaigns [66, 67] and strategically promote

289 products as environmentally friendly [67, 68] or their brands as charitable [69]. Intervention

290 strategies highlighting deception and manipulation by the tobacco industry have been among the

291 most effective strategies for deterring tobacco use [70]. By positioning ECs as the necessary

292 antidote to CCs, the tobacco industry uses distorted science and other forms of misinformation to

293 mobilize public support against regulation of ECs; potentially leveraging their own past

294 deception to permit unchecked promotion of ECs to a generation of non-smokers. Previous

295 research supports the use of news literacy campaigns and expert correction as strategies for

296 combatting misinformation. Moreover, in addition to the importance of monitoring the channels

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297 through which problematic information spreads to vulnerable subpopulations, the US Surgeon

298 General's report on health misinformation highlights the importance of "prebunking" to

299 inoculate the public to the sorts of misinformation they are likely to encounter [71, 72].

300   A crucial reason to monitor the spread of distorted science and other forms of

301 misinformation about nicotine on social media is that beliefs about nicotine are associated with

302 individual behavior, notably nicotine product curiosity, susceptibility, and use [5]. However, this

303 research focuses on the relationship between distorted science and industry attitudes because

304 efforts intended to mobilize political opposition to regulation on social media exemplified by

305 hashtags like #wevapewevote or #flavorssavelives often rely on misinformation [73]. Such

306 misinformation is problematic beyond the scope of behavior, as favorable public opinion is

307 integral to the success of tobacco control policies [74-76]. It appears that more antagonistic

308 views of the tobacco industry are tied to greater support for tobacco industry regulation [21].

309 There is substantial evidence supporting the problematic influence of misinformation on

310 behavior in the context of nicotine and tobacco [4, 8, 9, 77]. However, future research should

311 more closely examine the specific effects of distorted science on individual behavior as well.

312 *Limitations*

313   These data offer evidence of associations between self-reported social media use, beliefs,

314 and recall in a convenience sample. Although we provide evidence of an association between use

315 of specific social media platforms and recall and belief in mis and disinformation, we do not

316 assess whether exposure to such information occurred on social media in general or any specific

317 platform. Thus, while the proliferation of misinformation on social media is a well-documented

318 phenomenon [35, 45], our data do not provide definitive evidence that misinformation is more

319 likely to spread on Twitter versus Reddit, but rather that Twitter users are more likely to recall

320 and believe such information, whereas Reddit users are less likely.

321   As with any survey, inferences about causality or effect sizes at a population level are

322 limited. Moreover, methods used to maintain data quality for online opt-in surveys such as the

323 attention checks we used may pose further limitations to studying the people most susceptible to

324 misinformation. Although it is best practice not to over-interpret responses from respondents

325 screened out by such attention checks, we note that recall and belief of distorted science was

326 significantly higher among those who failed them. Thus, methodological approaches to studying

327 misinformation should account for the fact that the same inattentiveness we use to screen

328 responses for surveys may also screen out misinformation-susceptible participants. Though our

329 estimates likely differ from general population parameters, this study provides robust evidence

330 that young adult EC users are more likely to recall and believe misinformation about the effects

331 of the products they use. In addition to experimental designs better equipped to assess causality,

332 future research should examine not only how social media spreads misinformation, but also how

333 the characteristics that differ between platforms influence patterns of dissemination across

334 platforms.

335   Additionally, self-reported measurements of social media use are limited [78]. We

336 followed best practice recommendations in social media use measurement, however, there

337 remain inherent limitations regarding how accurately people recall and report social media use

338 which undoubtedly affect our results. To compensate for this limitation, we adopted a

339 conservative approach in including all of the social media platforms in the same model,

340 essentially controlling for use of all social media when estimating the odds ratio of any single

341 platform. As a result, non-significant findings for misinformation on Facebook (for example)

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342 should not be interpreted as suggesting such information does not exist on Facebook, but rather

343 that Reddit, Youtube, and Twitter, which were significant, are of higher priority with regards to

344 the dissemination of such information among this demographic. Future research using

345 unobtrusive measures like logs from big data sources are needed.

346 *Conclusions*

347   Public understanding of the health impact of nicotine is currently mired by uncertainty.

348 Although there is currently no significant evidence supporting therapeutic benefits of nicotine

349 use, misinformation ostensibly backed by "science" is being disseminated on social media and

350 potentially facilitating good will towards the tobacco industry. In light of a long-documented

351 history of interfering in the scientific process and disseminating misinformation about its

352 products, the role of the tobacco industry in disseminating this information merits close

353 monitoring, significant countering messaging, and proactive inoculation against potentially

354 harmful narratives.

355

356 **AUTHOR CONTRIBUTIONS**

357 NS conceptualized the project with guidance and oversight from BS. NS and EK developed the

358 survey instrument. NS completed the analysis. NS developed the manuscript with assistance

359 from EK, JB and BS. All coauthors reviewed and revised the final draft.

360 **COMPETING INTERESTS**

361 Authors have declared no conflicts of interest.

362 **FUNDING**

363   This research received no specific grant from any funding agency in the public, commercial or

364   not-for-profit sectors.

DATA AVAILABILITY

366   Data used in this study is housed at Truth Initiative and is not publicly available. Any inquiries

367   can be directed to the first author.

ETHICS APPROVAL STATEMENT

369   This study was determined exempt from review by a private review board, Advarra IRB,

370   (Pro00053405), as the research was conducted at a non-profit organization unaffiliated with an

371   institution. The study was determined exempt in accordance with the Department of Health and

372   Human Services regulations found at 45 CFR 46.104(d)(2). Specifically, as the information

373   collected from these adult participants could not be used to personally identify them or present

374   an undue risk by way of their responses.

19

375 **REFERENCES**

376 [1]   Czoli CD, Fong GT, Mays D, *et al.* How do consumers perceive differences in risk across
377 nicotine products? A review of relative risk perceptions across smokeless tobacco, e-cigarettes, nicotine
378 replacement therapy and combustible cigarettes. *Tobacco Control* 2017;**26**(e1):e49.
379 [2]   Hajek P, Phillips-Waller A, Przulj D, *et al.* A Randomized Trial of E-Cigarettes versus Nicotine-
380 Replacement Therapy. *New England Journal of Medicine* 2019;**380**(7):629-637.
381 [3]   Soneji SS, Sung H-Y, Primack BA, *et al.* Quantifying population-level health benefits and harms
382 of e-cigarette use in the United States. *PLOS ONE* 2018;**13**(3):e0193328.
383 [4]   Luk TT, Zhao S, Weng X, *et al.* Exposure to health misinformation about COVID-19 and
384 increased tobacco and alcohol use: a population-based survey in Hong Kong. *Tobacco Control*
385 2020:tobaccocontrol-2020-055960.
386 [5]   Villanti AC, Naud S, West JC, *et al.* Prevalence and correlates of nicotine and nicotine product
387 perceptions in U.S. young adults, 2016. *Addictive Behaviors* 2019;**98**:106020.
388 [6]   Schillo B, Boonn A, Arendt M, *et al.* Educating the public and lawmakers about tobacco industry
389 interference. *Tob Induc Dis* 2021;**19**:4-4.
390 [7]   McInerney JD, Dougherty MJ. Abusing science. *FASEB BioAdvances* 2020;**2**(10):587-595.
391 [8]   Chou W-YS, Oh A, Klein WMP. Addressing Health-Related Misinformation on Social Media.
392 *JAMA* 2018;**320**(23):2417-2418.
393 [9]   Tan ASL, Bigman CA. Misinformation About Commercial Tobacco Products on Social Media—
394 Implications and Research Opportunities for Reducing Tobacco-Related Health Disparities. *American*
395 *Journal of Public Health* 2020;**110**(S3):S281-S283.
396 [10]   Dewhirst T. Co-optation of harm reduction by Big Tobacco. *Tobacco Control*
397 2020:tobaccocontrol-2020-056059.
398 [11]   Shi R, Feldman R, Liu J, *et al.* The Dilemma of Correcting Nicotine Misperceptions: Nicotine
399 Replacement Therapy versus Electronic Cigarettes. *Health Communication* 2020:1-11.
400 [12]   Wackowski OA, Delnevo CD. Young Adults' Risk Perceptions of Various Tobacco Products
401 Relative to Cigarettes: Results From the National Young Adult Health Survey. *Health Education &*
402 *Behavior* 2015;**43**(3):328-336.
403 [13]   Steinberg MB, Bover Manderski MT, Wackowski OA, *et al.* Nicotine Risk Misperception
404 Among US Physicians. *Journal of general internal medicine* 2020.
405 [14]   Pacek LR, Rass O, Johnson MW. Knowledge about nicotine among HIV-positive smokers:
406 Implications for tobacco regulatory science policy. *Addictive Behaviors* 2017;**65**:81-86.
407 [15]   Patel D, Peiper N, Rodu B. Perceptions of the health risks related to cigarettes and nicotine
408 among university faculty. *Addiction Research & Theory* 2013;**21**(2):154-159.
409 [16]   Biebert A. You Don't Know Nicotine. 2020.
410 [17]   Norcia A. Why Are Smokers Being Hospitalized Less Often From Coronavirus? *VICE* 2020.
411 [18]   Hair EC, Bennett M, Sheen E, *et al.* Examining perceptions about IQOS heated tobacco product:
412 consumer studies in Japan and Switzerland. *Tobacco Control* 2018;**27**(Suppl 1):s70.
413 [19]   Robichaud MO, Seidenberg AB, Byron MJ. Tobacco companies introduce 'tobacco-free' nicotine
414 pouches. *Tobacco Control* 2020;**29**(e1):e145.
415 [20]   Sears CG, Walker KL, Hart JL, *et al.* Clean, cheap, convenient: promotion of electronic cigarettes
416 on YouTube. *Tobacco prevention cessation* 2017;**3**.
417 [21]   Chen J, Ho SY, Leung LT, *et al.* Adolescent Support for Tobacco Control Policies and
418 Associations with Tobacco Denormalization Beliefs and Harm Perceptions. *International Journal of*
419 *Environmental Research and Public Health* 2019;**16**(1).
420 [22]   Lappas AS, Tzortzi AS, Konstantinidi EM, *et al.* Short-term respiratory effects of e-cigarettes in
421 healthy individuals and smokers with asthma. *Respirology* 2018;**23**(3):291-297.
422 [23]   Miyashita L, Foley G. E-cigarettes and respiratory health: the latest evidence. *The Journal of*
423 *Physiology* 2020;**598**(22):5027-5038.

424 [24]   National Academies of Sciences E, Medicine. Public Health Consequences of E-Cigarettes.
425 Washington, DC: The National Academies Press 2018.
426 [25]   Benowitz NL. Emerging Nicotine Delivery Products. Implications for Public Health. *Annals of*
427 *the American Thoracic Society* 2014;**11**(2):231-235.
428 [26]   Bruin JE, Gerstein HC, Holloway AC. Long-Term Consequences of Fetal and Neonatal Nicotine
429 Exposure: A Critical Review. *Toxicological Sciences* 2010;**116**(2):364-374.
430 [27]   Dwyer JB, Broide RS, Leslie FM. Nicotine and brain development. *Birth Defects Research Part*
431 *C: Embryo Today: Reviews* 2008;**84**(1):30-44.
432 [28]   Slotkin TA, Skavicus S, Card J, *et al.* Developmental Neurotoxicity of Tobacco Smoke Directed
433 Toward Cholinergic and Serotonergic Systems: More Than Just Nicotine. *Toxicological Sciences*
434 2015;**147**(1):178-189.
435 [29]   Smith RF, McDonald CG, Bergstrom HC, *et al.* Adolescent nicotine induces persisting changes
436 in development of neural connectivity. *Neuroscience & Biobehavioral Reviews* 2015;**55**:432-443.
437 [30]   Heeschen C, Jang JJ, Weis M, *et al.* Nicotine stimulates angiogenesis and promotes tumor growth
438 and atherosclerosis. *Nature Medicine* 2001;**7**(7):833-839.
439 [31]   Morris Pamela B, Ference Brian A, Jahangir E, *et al.* Cardiovascular Effects of Exposure to
440 Cigarette Smoke and Electronic Cigarettes. *Journal of the American College of Cardiology*
441 2015;**66**(12):1378-1391.
442 [32]   Nordskog BK, Blixt AD, Morgan WT, *et al.* Matrix-degrading and pro-inflammatory changes in
443 human vascular endothelial cells exposed to cigarette smoke condensate. *Cardiovascular Toxicology*
444 2003;**3**(2):101-117.
445 [33]   Rejali M, Rejali AR, Zhang L, *et al.* Effects of nicotine on the cardiovascular system. *Vascular*
446 *Disease Prevention* 2005;**2**(2):135-144.
447 [34]   Albarracin D, Shavitt S. Attitudes and Attitude Change. *Annual Review of Psychology*
448 2018;**69**(1):299-327.
449 [35]   Soule EK, Mayne S, Snipes W, *et al.* Impacts of COVID-19 on Electronic Cigarette Purchasing,
450 Use and Related Behaviors. *International Journal of Environmental Research and Public Health*
451 2020;**17**(18).
452 [36]   Zhou C, Xiu H, Wang Y, *et al.* Characterizing the dissemination of misinformation on social
453 media in health emergencies: An empirical study based on COVID-19. *Information Processing &*
454 *Management* 2021;**58**(4):102554.
455 [37]   Farsalinos K, Barbouni A, Niaura R. Systematic review of the prevalence of current smoking
456 among hospitalized COVID-19 patients in China: could nicotine be a therapeutic option? *Internal and*
457 *Emergency Medicine* 2020;**15**(5):845-852.
458 [38]   Farsalinos K, Barbouni A, Poulas K, *et al.* Current smoking, former smoking, and adverse
459 outcome among hospitalized COVID-19 patients: a systematic review and meta-analysis. *Therapeutic*
460 *advances in chronic disease* 2020;**11**:2040622320935765.
461 [39]   Farsalinos K, Barbouni A, Niaura R. Smoking, vaping and hospitalization for COVID-19. *Qeios*
462 2020.
463 [40]   Changeux J-P, Amoura Z, Rey FA, *et al.* A nicotinic hypothesis for Covid-19 with preventive and
464 therapeutic implications. *Comptes Rendus Biolgies* 2020;**343**(1):33-39.
465 [41]   Gülsen A, Yigitbas BA, Uslu B, *et al.* The Effect of Smoking on COVID-19 Symptom Severity:
466 Systematic Review and Meta-Analysis. *Pulmonary medicine* 2020;**2020**:7590207.
467 [42]   Karanasos A, Aznaouridis K, Latsios G, *et al.* Impact of smoking status on disease severity and
468 mortality of hospitalized patients with COVID-19 infection: a systematic review and meta-analysis.
469 *Nicotine Tobacco Research* 2020.
470 [43]   Patanavanich R, Glantz SA. Smoking is associated with COVID-19 progression: a meta-analysis.
471 *Nicotine Tobacco Research* 2020;**22**(9):1653-1656.
472 [44]   Gupta AK, Nethan ST, Mehrotra R. Tobacco use as a well-recognized cause of severe COVID-19
473 manifestations. *Respiratory Medicine* 2021;**176**:106233.

[45]   Kavuluru R, Noh J, Rose SW. Twitter Discourse on Nicotine as Potential Prophylactic or Therapeutic for COVID-19. *medRxiv* 2021:2021.001.2005.21249284.

[46]   Kwon M, Park E. Perceptions and sentiments about electronic cigarettes on social media platforms: systematic review. *JMIR Public Health Surveillance* 2020;**6**(1):e13673.

[47]   Lazard AJ, Saffer AJ, Wilcox GB*, et al.* E-cigarette social media messages: a text mining analysis of marketing and consumer conversations on Twitter. *JMIR Public Health Surveillance* 2016;**2**(2):e6551.

[48]   Majmundar A, Moran MB. For or Against Tobacco Control: Sponsored Tobacco Advocacy Messages on Facebook and Instagram. *Nicotine & Tobacco Research* 2021.

[49]   Trifiro BM, Gerson J. Social Media Usage Patterns: Research Note Regarding the Lack of Universal Validated Measures for Active and Passive Use. *Social Media + Society* 2019;**5**(2):2056305119848743.

[50]   Robertson OH, Bigg E, Puck TT*, et al.* THE BACTERICIDAL ACTION OF PROPYLENE GLYCOL VAPOR ON MICROORGANISMS SUSPENDED IN AIR. I. *J Exp Med* 1942;**75**(6):593-610.

[51]   Miech R, Leventhal A, Johnston L*, et al.* Trends in Use and Perceptions of Nicotine Vaping Among US Youth From 2017 to 2020. *JAMA Pediatrics* 2021;**175**(2):185-190.

[52]   Mitchell JT, Weisner TS, Jensen PS*, et al.* How Substance Users With ADHD Perceive the Relationship Between Substance Use and Emotional Functioning. *Journal of Attention Disorders* 2017;**22**(9_suppl):49S-60S.

[53]   Xian S, Chen Y. E-cigarette users are associated with asthma disease: A meta-analysis. *The Clinical Respiratory Journal* 2021;**15**(5):457-466.

[54]   Zarocostas J. How to fight an infodemic. *The Lancet* 2020;**395**(10225):676.

[55]   Kearney MD, Chiang SC, Massey PM. The Twitter origins and evolution of the COVID-19 "plandemic" conspiracy theory. *Harvard Kennedy School Misinformation Review* 2020;**1**(3).

[56]   Chen E, Lerman K, Ferrara E. Tracking social media discourse about the covid-19 pandemic: Development of a public coronavirus twitter data set. *JMIR Public Health Surveillance* 2020;**6**(2):e19273.

[57]   Collins L, Glasser AM, Abudayyeh H*, et al.* E-Cigarette Marketing and Communication: How E-Cigarette Companies Market E-Cigarettes and the Public Engages with E-cigarette Information. *Nicotine & Tobacco Research* 2019;**21**(1):14-24.

[58]   Vraga EK, Bode L. Defining Misinformation and Understanding its Bounded Nature: Using Expertise and Evidence for Describing Misinformation. *Political Communication* 2020;**37**(1):136-144.

[59]   Leonardi PM, Nardi BA, Kallinikos J. Materiality and organizing: Social interaction in a technological world: Oxford university press on demand 2012.

[60]   Allem J-P, Dormanesh A, Majmundar A*, et al.* Topics of Nicotine-Related Discussions on Twitter: Infoveillance Study. *J Med Internet Res* 2021;**23**(6):e25579.

[61]   Record RA, Silberman WR, Santiago JE*, et al.* I Sought It, I Reddit: Examining Health Information Engagement Behaviors among Reddit Users. *Journal of Health Communication* 2018;**23**(5):470-476.

[62]   Sowles SJ, Krauss MJ, Gebremedhn L*, et al.* "I feel like I've hit the bottom and have no idea what to do": Supportive social networking on Reddit for individuals with a desire to quit cannabis use. *Substance Abuse* 2017;**38**(4):477-482.

[63]   Auxier B, Anderson M. Social Media Use in 2021. Pew Research Center 2021.

[64]   Henningfield JE, Rose CA, Zeller M. Tobacco industry litigation position on addiction: continued dependence on past views. *Tobacco Control* 2006;**15**(suppl 4):iv27.

[65]   Campaign for Tobacco-Free Kids. Big Tobacco is Exploiting COVID-19 to Market its Harmful Products. 2021 Date;Volume.

[66]   Hirschhorn N. Corporate social responsibility and the tobacco industry: hope or hype? *Tobacco Control* 2004;**13**(4):447.

[67]   University of Bath. CSR Strategy Tobacco Tactics 2021 Date;Volume. https://tobaccotactics.org/wiki/csr-strategy/.

[68]   Epperson AE, Lambin EF, Henriksen L*, et al.* Natural American Spirit's pro-environment packaging and perceptions of reduced-harm cigarettes. *Preventive medicine* 2019;**126**:105782.

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525 [69] Fooks GJ, Gilmore AB. Corporate Philanthropy, Political Influence, and Health Policy. *PLOS*
526 *ONE* 2013;**8**(11):e80864.
527 [70] Malone RE, Grundy Q, Bero LA. Tobacco industry denormalisation as a tobacco control
528 intervention: a review. *Tobacco Control* 2012;**21**(2):162.
529 [71] Donovan J. Concrete Recommendations for Cutting Through Misinformation During the
530 COVID-19 Pandemic. *American Journal of Public Health* 2020;**110**(S3):S286-S287.
531 [72] Murthy VH. Confronting Health Misinformation: The U.S. Surgeon General's Advisory on
532 Building a Healthy Information Environment. 2021.
533 [73] Williams Kirkpatrick A. The spread of fake science: Lexical concreteness, proximity,
534 misinformation sharing, and the moderating role of subjective knowledge. *Public Understanding of*
535 *Science* 2020;**30**(1):55-74.
536 [74] Boynton MH, Agans RP, Bowling JM*, et al.* Understanding how perceptions of tobacco
537 constituents and the FDA relate to effective and credible tobacco risk messaging: A national phone survey
538 of U.S. adults, 2014–2015. *BMC Public Health* 2016;**16**(1):516.
539 [75] Kowitt SD, Goldstein AO, Schmidt AM*, et al.* Attitudes toward FDA regulation of newly deemed
540 tobacco products. *Tobacco Regulatory Science* 2017;**3**(4):504-515.
541 [76] Schmidt AM, Kowitt SD, Myers AE*, et al.* Attitudes towards Potential New Tobacco Control
542 Regulations among U.S. Adults. *International Journal of Environmental Research and Public Health*
543 2018;**15**(1).
544 [77] Lee SJ, Sanders-Jackson A, Tan ASL. Effects of Current and Enhanced Tobacco Corrective
545 Messages on Smokers' Intention to Quit Smoking and Intention to Purchase Cigarettes. *Nicotine &*
546 *Tobacco Research* 2020;**22**(4):569-575.
547 [78] de Vreese CH, Neijens P. Measuring Media Exposure in a Changing Communications
548 Environment. *Communication Methods and Measures* 2016;**10**(2-3):69-80.

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557 **TABLES:**

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Table 1. Social media use by platform (N = 1225)

Platform	Have ever used	Use index[a] M	(SD)
Facebook	78.90%	1.73	(1.13)
Instagram	67.00%	1.41	(1.15)
Reddit	28.50%	0.50	(0.09)
Snapchat	51.90%	1.14	(1.22)
TikTok	45.10%	0.88	(1.10)
Twitter	40.60%	0.65	(0.89)
Youtube	80.90%	1.43	(0.98)

[a]Use index refers to an average of how often participants check, post, and respond to content on each platform on a four-point scale from anchored (0) "never" to (3) "often"

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TABLE 2. SOCIAL MEDIA PLATFORM USE PREDICTING RECALL AND BELIEF IN MISLEADING INFORMATION

	Recall distorted science COVID-19			Recall distorted science general			Believe distorted science COVID-19			Believe distorted science general		
	OR	LLCI	ULCI	OR	LLCI	ULCI	OR	LLCI	ULCI	OR	LLCI	ULCI
FEMALE	**0.45**	**(0.33**	**0.61)**	**0.67**	**(0.53**	**0.86)**	**0.50**	**(0.35**	**0.70)**	**0.63**	**(0.49**	**0.82)**
NON-HISPANIC BLACK	**2.00**	**(1.38**	**2.89)**	*1.33*	*(0.96*	*1.85)*	**2.46**	**(1.65**	**3.67)**	**1.44**	**(1.02**	**2.02)**
HISPANIC	1.33	(0.90	1.98)	1.30	(0.93	1.83)	1.09	(0.69	1.72)	0.90	(0.64	1.27)
HS^A	1.07	(0.78	1.46)	1.19	(0.94	1.50)	1.01	(0.72	1.41)	**1.31**	**(1.03**	**1.66)**
CURRENTECIG^B	**1.73**	**(1.25**	**2.39)**	**1.64**	**(1.29**	**2.09)**	**1.91**	**(1.36**	**2.67)**	**1.96**	**(1.54**	**2.50)**
AGE	1.00	(0.96	1.03)	**0.97**	**(0.94**	**0.99)**	0.99	(0.95	1.02)	1.00	(0.97	1.02)
FACEBOOK	0.98	(0.84	1.14)	1.10	(0.97	1.23)	1.06	(0.91	1.24)	1.08	(0.96	1.22)
INSTAGRAM	1.01	(0.86	1.19)	1.00	(0.88	1.12)	0.98	(0.82	1.17)	0.99	(0.87	1.12)
REDDIT	0.86	(0.72	1.04)	1.06	(0.93	1.22)	**0.72**	**(0.59**	**0.88)**	0.92	(0.80	1.06)
SNAPCHAT	1.00	(0.87	1.16)	0.94	(0.85	1.05)	1.00	(0.86	1.16)	1.03	(0.92	1.15)
TIKTOK	1.11	(0.95	1.29)	1.05	(0.93	1.18)	0.97	(0.82	1.14)	*1.11*	*(0.98*	*1.25)*
TWITTER	**1.21**	**(1.01**	**1.44)**	1.12	(0.97	1.28)	**1.26**	**(1.04**	**1.52)**	*1.16*	*(0.99*	*1.35)*
YOUTUBE	1.06	(0.89	1.26)	0.97	(0.85	1.11)	**1.32**	**(1.09**	**1.60)**	0.97	(0.85	1.11)

95% CONFIDENCE INTERVALS ARE CALCULATED USING ROBUST STANDARD ERRORS. ODDS RATIOS IN ITALICS ARE MARGINALLY SIGNIFICANT AT *P* < .1 WHILE THOSE IN BOLD ARE SIGNIFICANT AT *P* < .05. ^ADUMMY CODE FOR HAVING A HIGH SCHOOL DIPLOMA/GED OR LESS EDUCATION. ^BDUMMY CODE FOR HAVING USED E-CIGARETTE IN THE PAST 30 DAYS

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TABLE 3. RECALL AND ACCEPTANCE PREDICTING INDUSTRY BELIEFS

	Positive beliefs			Negative beliefs		
	OR	LLCI	ULCI	OR	LLCI	ULCI
FEMALE	1.05	(0.84	1.32)	1.13	(0.90	1.41)
NON-HISPANIC BLACK	1.02	(0.75	1.38)	1.07	(0.78	1.45)
HISPANIC	1.07	(0.77	1.48)	**1.44**	**(1.07**	**1.96)**
HS[A]	0.97	(0.78	1.21)	**0.63**	**(0.51**	**0.78)**
CURRENTECIG	**1.69**	**(1.35**	**2.12)**	**0.65**	**(0.52**	**0.82)**
AGE	1.02	(0.99	1.04)	0.99	(0.97	1.01)
RECALL DISTORTED SCIENCE COVID-19	1.20	(0.99	1.46)	0.98	(0.82	1.19)
RECALL DISTORTED SCIENCE GENERAL	**1.26**	**(1.07**	**1.47)**	0.99	(0.86	1.15)
BELIEVE DISTORTED SCIENCE COVID-19	**1.61**	**(1.34**	**1.95)**	1.05	(0.88	1.25)
BELIEVE DISTORTED SCIENCE GENERAL	**1.28**	**(1.09**	**1.50)**	**1.18**	**(1.02**	**1.35)**

95% CONFIDENCE INTERVALS ARE CALCULATED USING ROBUST STANDARD ERRORS. ODDS RATIOS IN ITALICS ARE MARGINALLY SIGNIFICANT AT $P < .1$ WHILE THOSE IN BOLD ARE SIGNIFICANT AT $P < .05$. [A]DUMMY CODE FOR HAVING A HIGH SCHOOL DIPLOMA/GED OR LESS EDUCATION [B]DUMMY CODE FOR HAVING USED E-CIGARETTE IN THE PAST 30 DAYS

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STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page	Line
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2	5
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2	2-25
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-7	48-125
Objectives	3	State specific objectives, including any prespecified hypotheses	7	122-125
Methods				
Study design	4	Present key elements of study design early in the paper	7	129-132
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7	129-135
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7	129-135
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10	143-187
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-10	143-187
Bias	9	Describe any efforts to address potential sources of bias	10	189-194
Study size	10	Explain how the study size was arrived at	7	129-135
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10	143-187
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10	189-194
		(*b*) Describe any methods used to examine subgroups and interactions		n/a
		(*c*) Explain how missing data were addressed	7	132-135
		(*d*) If applicable, describe analytical methods taking account of sampling strategy		n/a
		(*e*) Describe any sensitivity analyses		n/a
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7	132-135
		(b) Give reasons for non-participation at each stage		n/a
		(c) Consider use of a flow diagram		n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8	135-139
		(b) Indicate number of participants with missing data for each variable	7	132-

			of interest		135
Outcome data	15*		Report numbers of outcome events or summary measures	25	Table 1
Main results	16		(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	26-27	Table 2, Table 3
			(*b*) Report category boundaries when continuous variables were categorized		n/a
			(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		n/a
Other analyses	17		Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses		n/a
Discussion					
Key results	18		Summarise key results with reference to study objectives	11	223-228
Limitations	19		Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15	289-314
Interpretation	20		Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15	315-321
Generalisability	21		Discuss the generalisability (external validity) of the study results	14	293-295
Other information					
Funding	22		Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16	330

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.